US 20080192234A1

(19) **United States**

(12) **Patent Application Publication**

Lapstun et al.

(10) **Pub. No.: US 2008/0192234 A1**

(43) **Pub. Date: Aug. 14, 2008**

(54) **METHOD OF SENSING MOTION OF A SENSING DEVICE RELATIVE TO A SURFACE**

(75) Inventors: **Paul Lapstun**, Balmain (AU); **Kia Silverbrook**, Balmain (AU)

Correspondence Address:
SILVERBROOK RESEARCH PTY LTD
393 DARLING STREET
BALMAIN 2041

(73) Assignee: **Silverbrook Research Pty Ltd**

(21) Appl. No.: **12/015,507**

(22) Filed: **Jan. 17, 2008**

Related U.S. Application Data

(60) Provisional application No. 60/888,775, filed on Feb. 8, 2007.

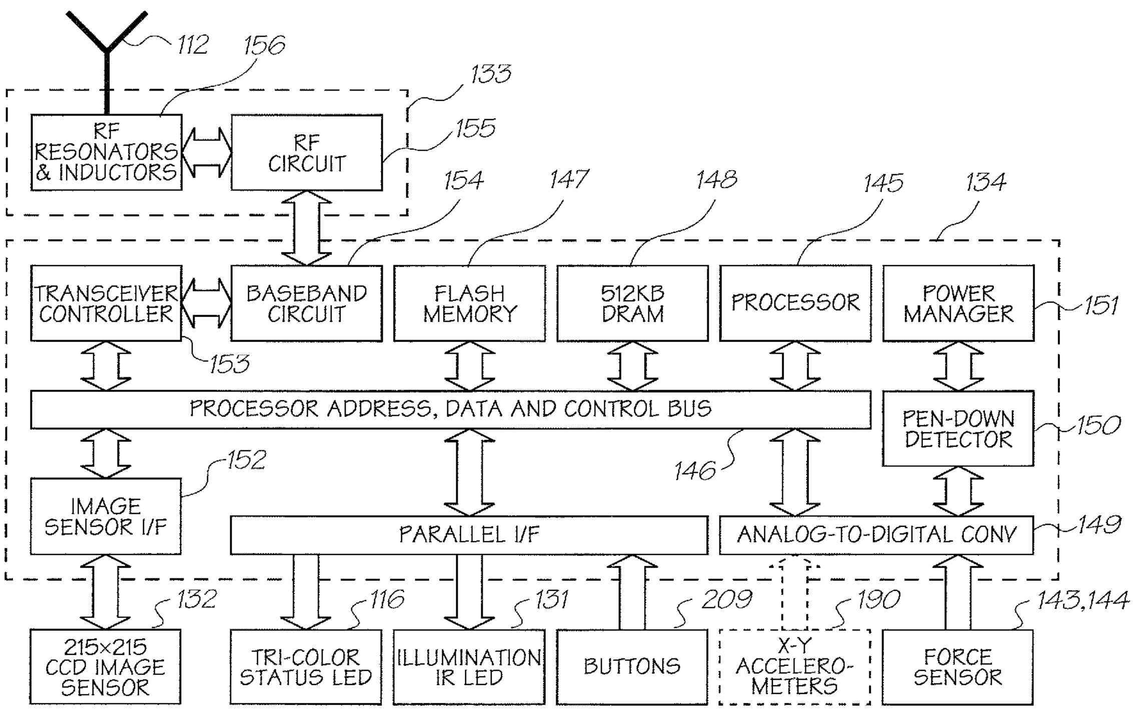
Publication Classification

(51) **Int. Cl.**
G01N 21/00 (2006.01)
G01B 11/14 (2006.01)

(52) **U.S. Cl.** **356/72**; 356/620

(57) **ABSTRACT**

A method of sensing motion of a sensing device relative to a surface, the method including the steps of: optically imaging a position-coding pattern disposed on or in the surface; independently sensing relative position changes of the sensing device using a motion sensor; generating absolute motion data by determining a plurality of absolute positions of the sensing device relative to the surface using the imaged position-coding pattern; independently generating relative motion data using the relative position changes sensed by the motion sensor; and determining the motion of the sensing device using the absolute motion data supplemented with the relative motion data.



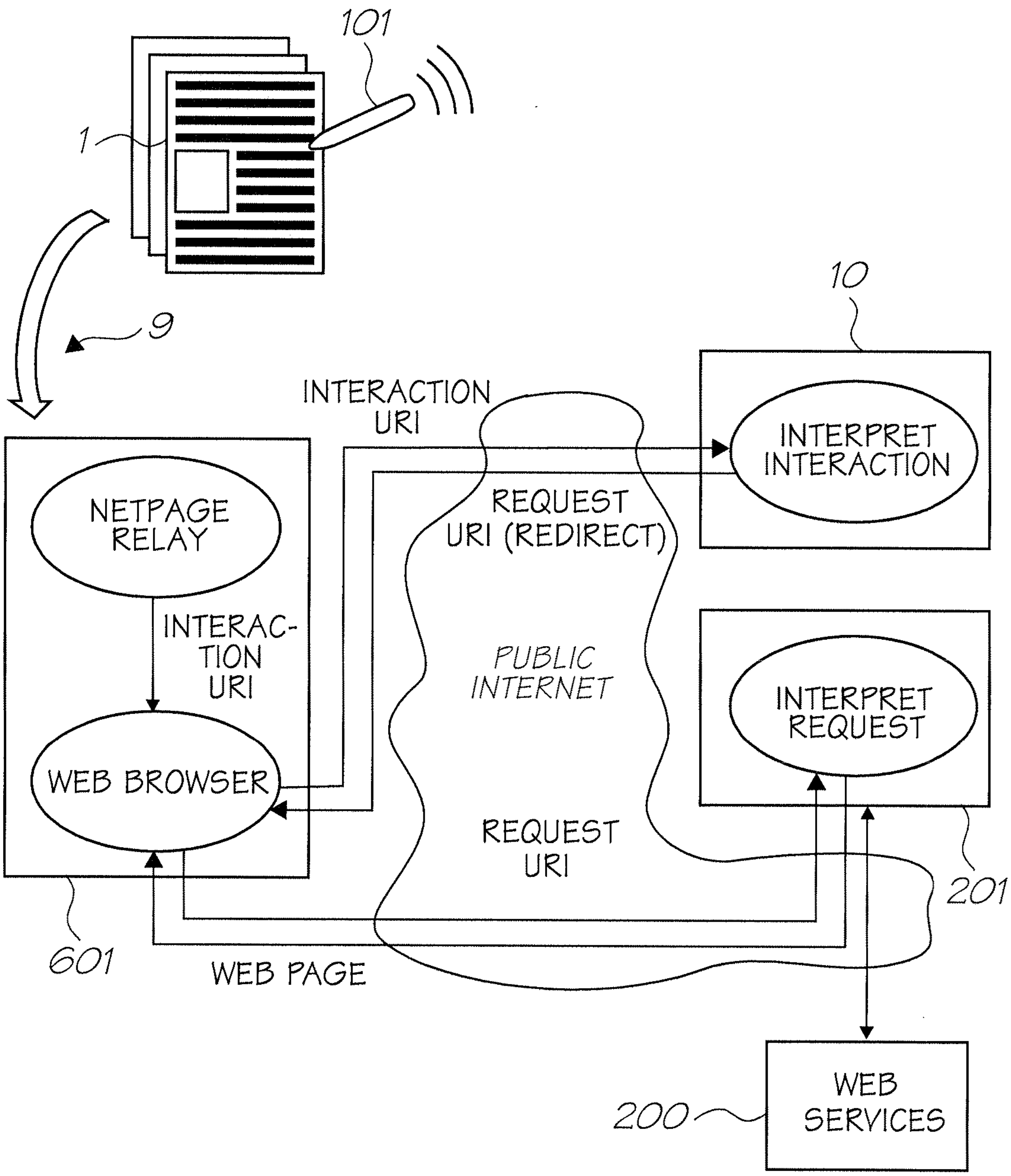

101
1
9
10
INTERACTION URI
INTERPRET INTERACTION
NETPAGE RELAY
REQUEST URI (REDIRECT)
INTERACTION URI
PUBLIC INTERNET
INTERPRET REQUEST
WEB BROWSER
REQUEST URI
201
601
WEB PAGE
WEB SERVICES
200

FIG. 1

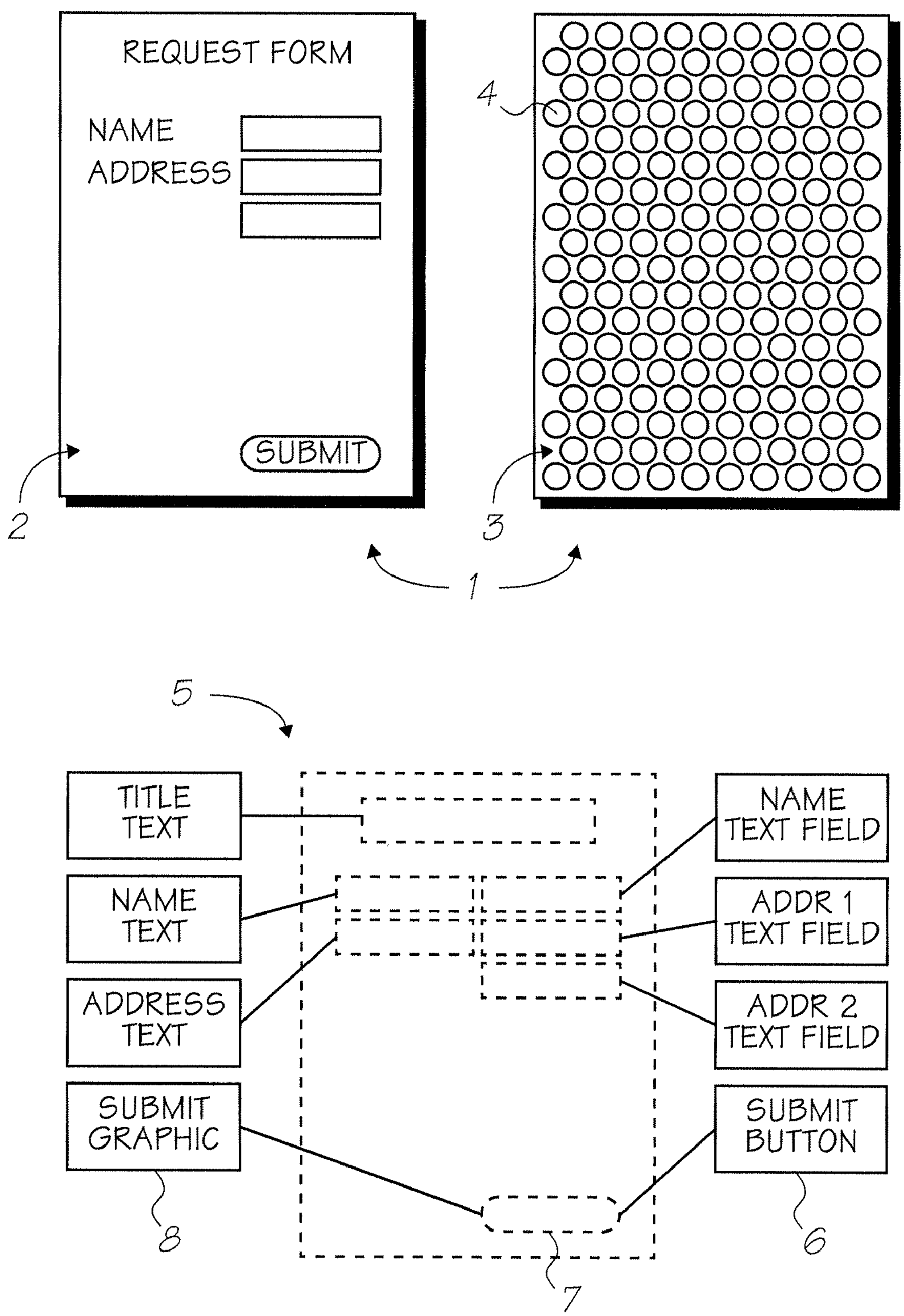

REQUEST FORM
NAME
ADDRESS
SUBMIT
4
2
3
1
5
TITLE TEXT
NAME TEXT
ADDRESS TEXT
SUBMIT GRAPHIC
NAME TEXT FIELD
ADDR 1 TEXT FIELD
ADDR 2 TEXT FIELD
SUBMIT BUTTON
8
6
7

FIG. 2

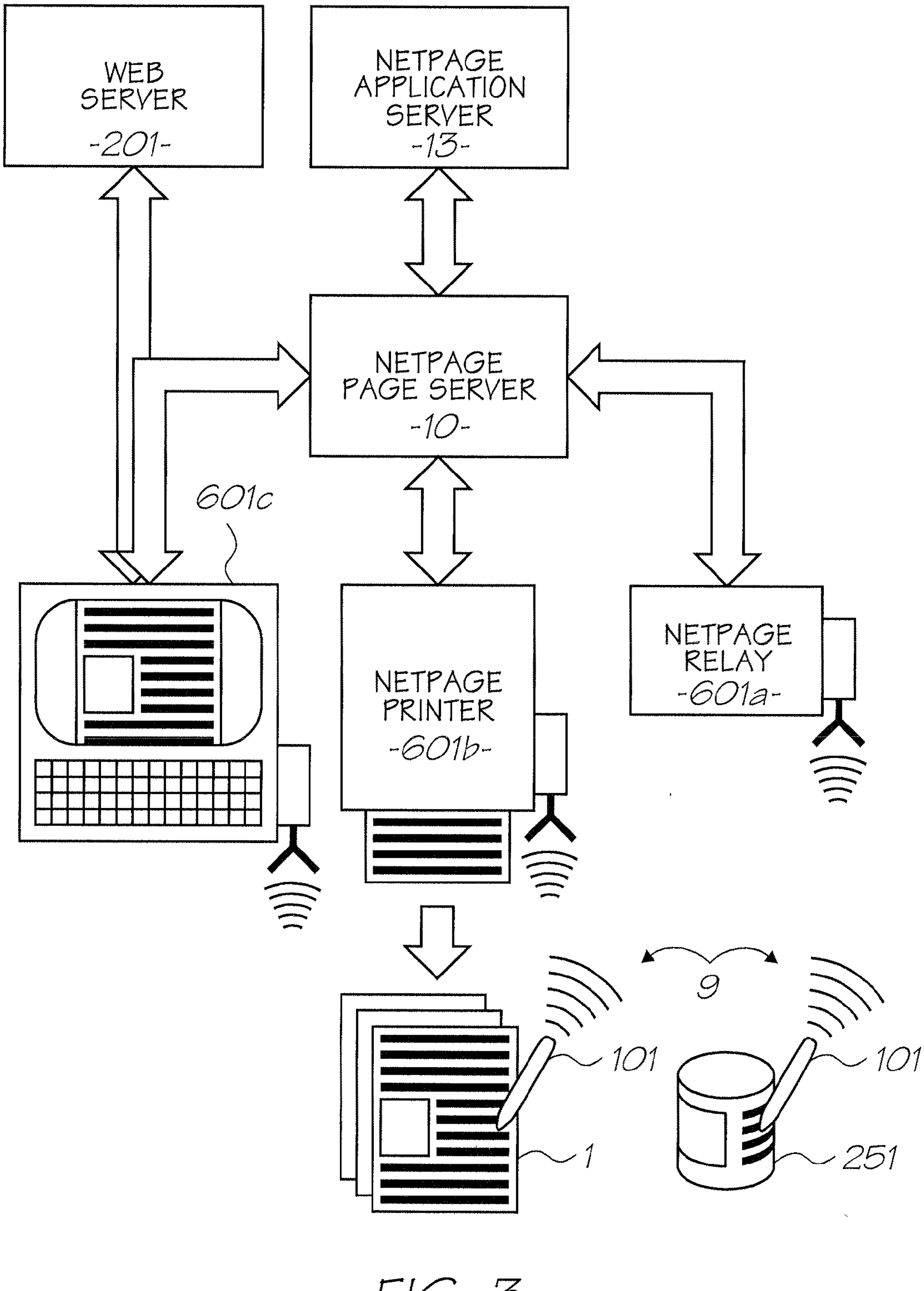
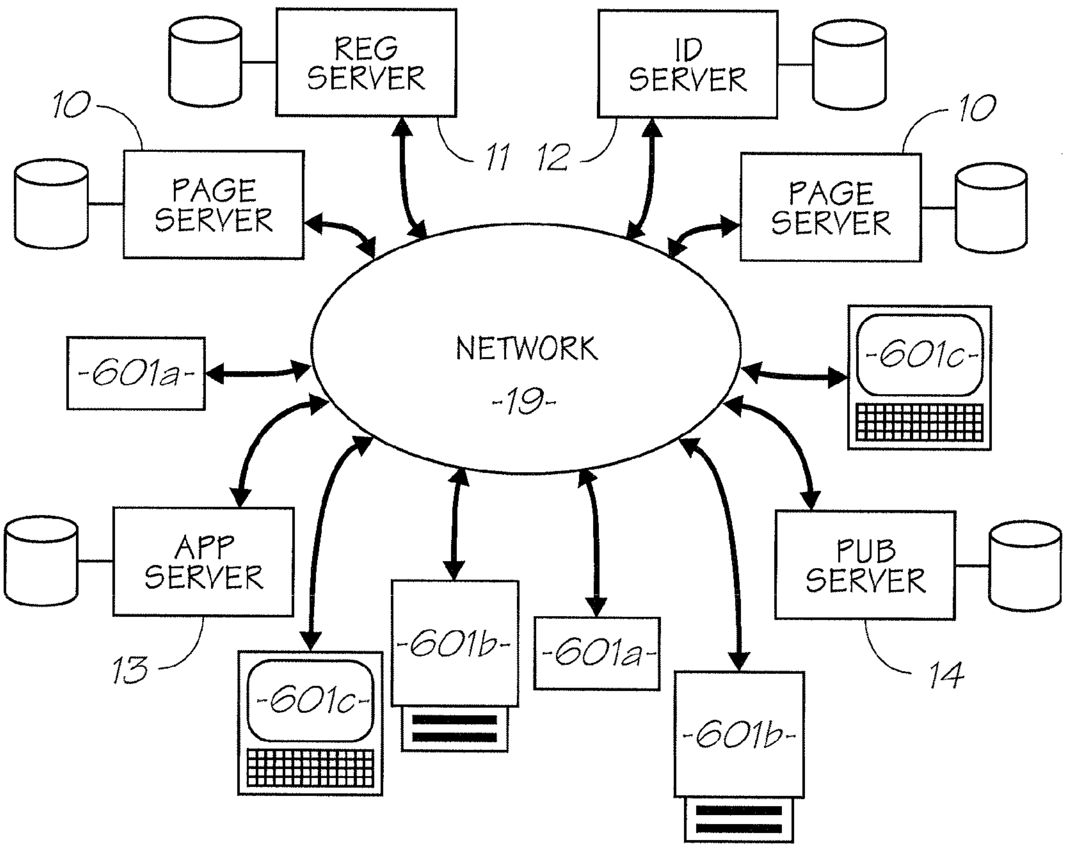

WEB SERVER
-201-
NETPAGE APPLICATION SERVER
-13-
NETPAGE PAGE SERVER
-10-
601c
NETPAGE PRINTER
-601b-
NETPAGE RELAY
-601a-
9
101
101
1
251

FIG. 3



REG SERVER
ID SERVER
10
11
12
10
PAGE SERVER
PAGE SERVER
NETWORK
-19-
-601a-
-601c-
APP SERVER
PUB SERVER
13
14
-601c-
-601b-
-601a-
-601b-

FIG. 3A

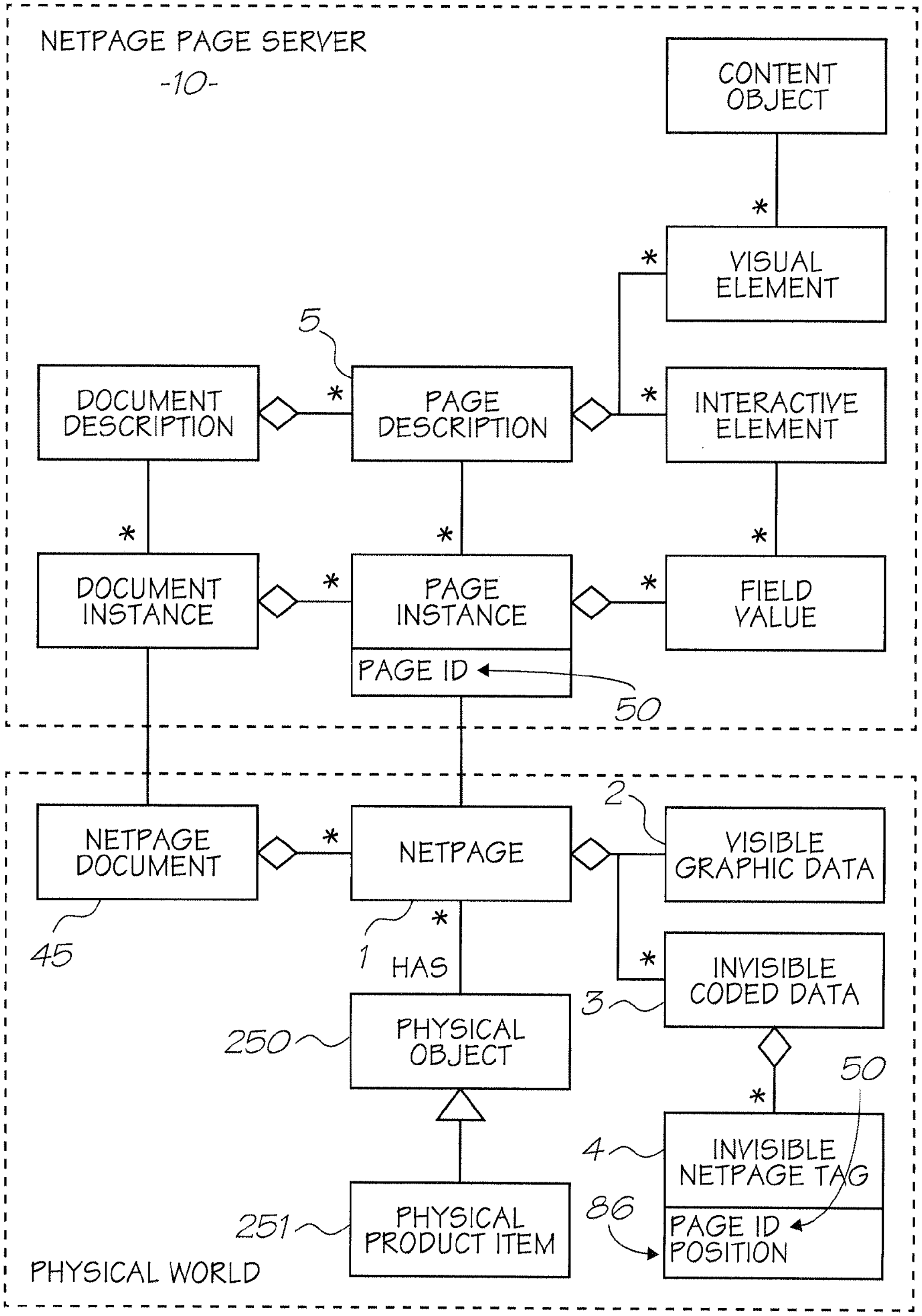

NETPAGE PAGE SERVER
-10-
CONTENT OBJECT
*
VISUAL ELEMENT
*
5
DOCUMENT DESCRIPTION
*
PAGE DESCRIPTION
*
INTERACTIVE ELEMENT
*
*
*
DOCUMENT INSTANCE
*
PAGE INSTANCE
PAGE ID
*
FIELD VALUE
50
2
NETPAGE DOCUMENT
*
NETPAGE
VISIBLE GRAPHIC DATA
45
1
*
HAS
*
INVISIBLE CODED DATA
3
250
PHYSICAL OBJECT
50
*
4
INVISIBLE NETPAGE TAG
86
PAGE ID
POSITION
251
PHYSICAL PRODUCT ITEM
PHYSICAL WORLD

FIG. 4

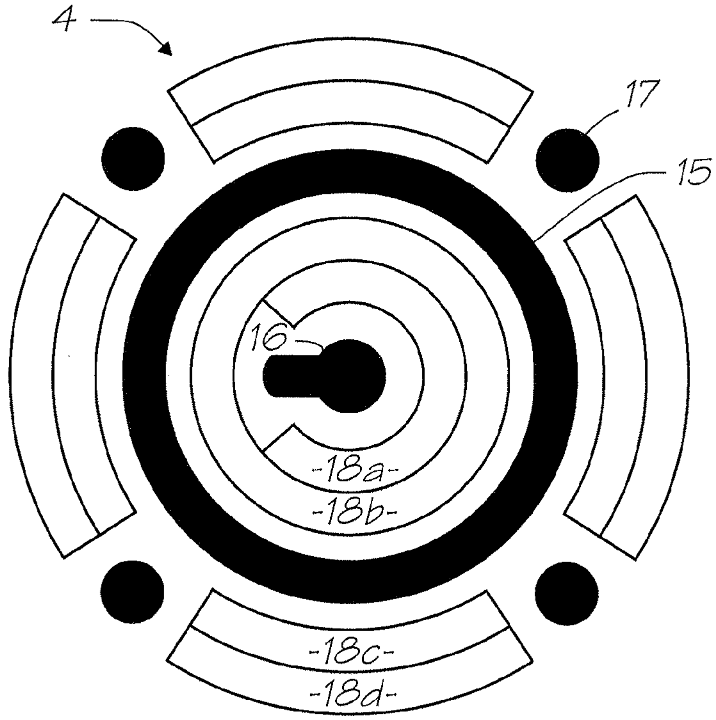


FIG. 5A

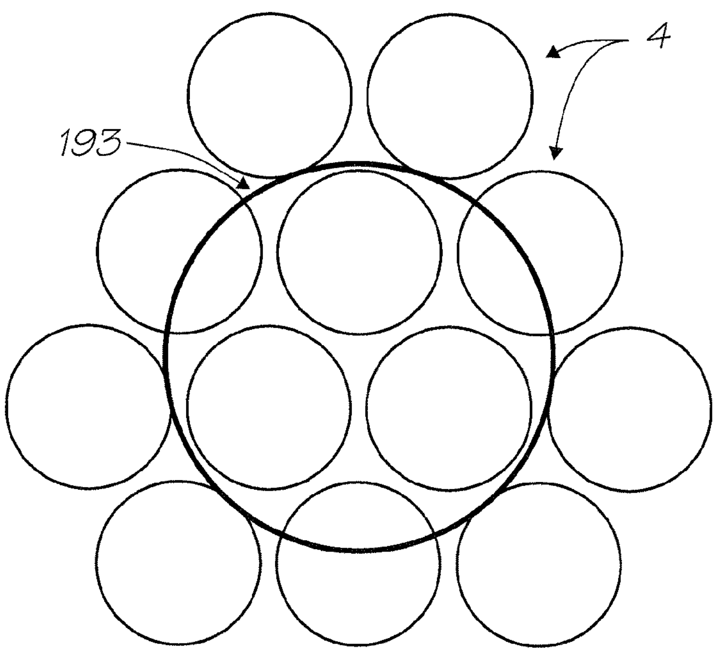


FIG. 5B

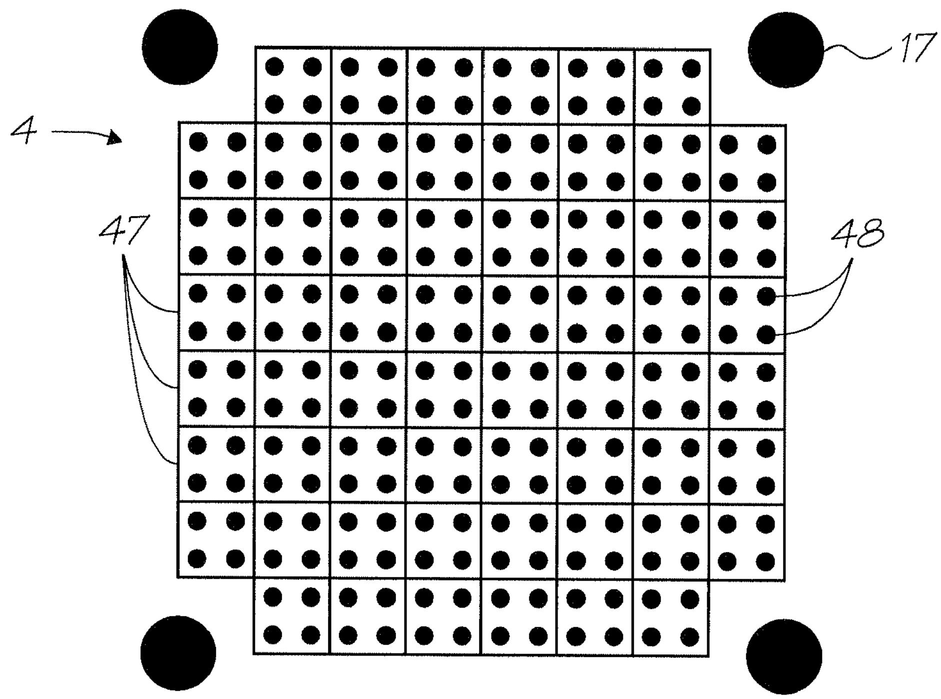


FIG. 6A

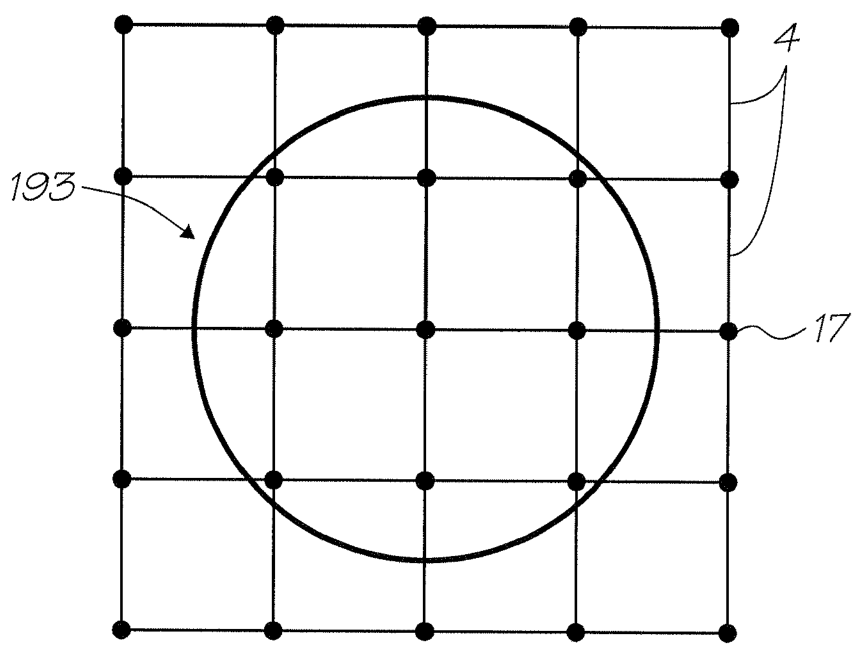


FIG. 6B

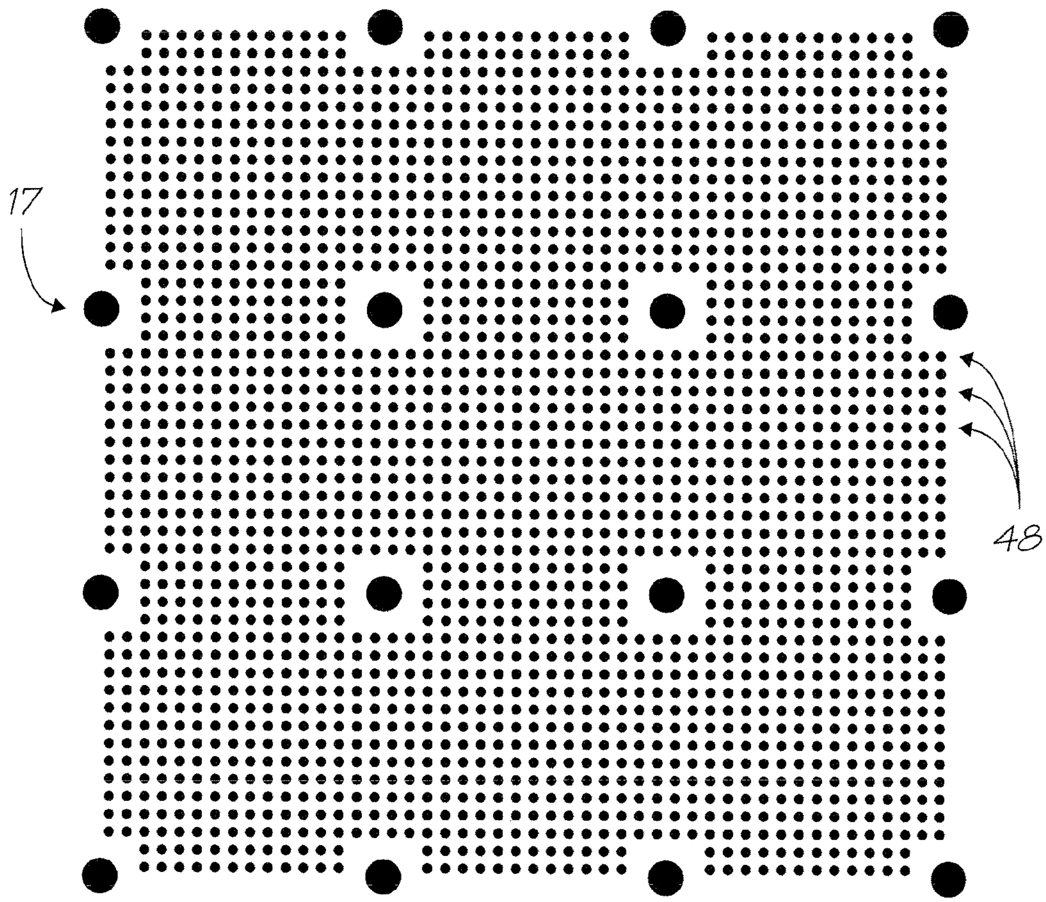


FIG. 6C

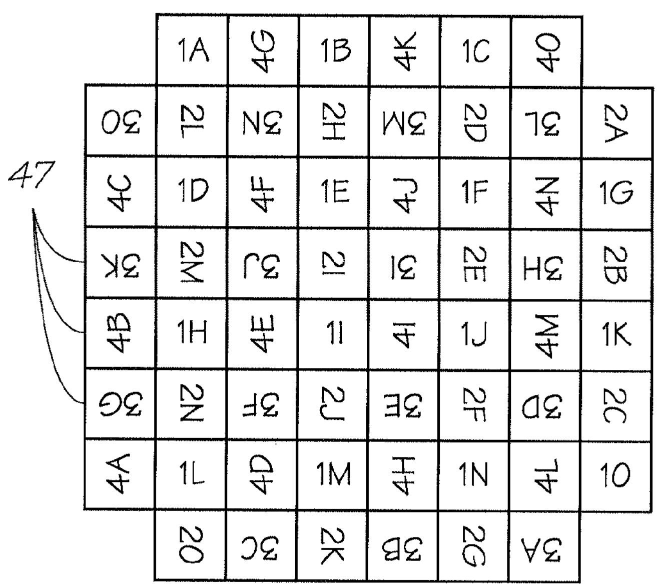


FIG. 6D

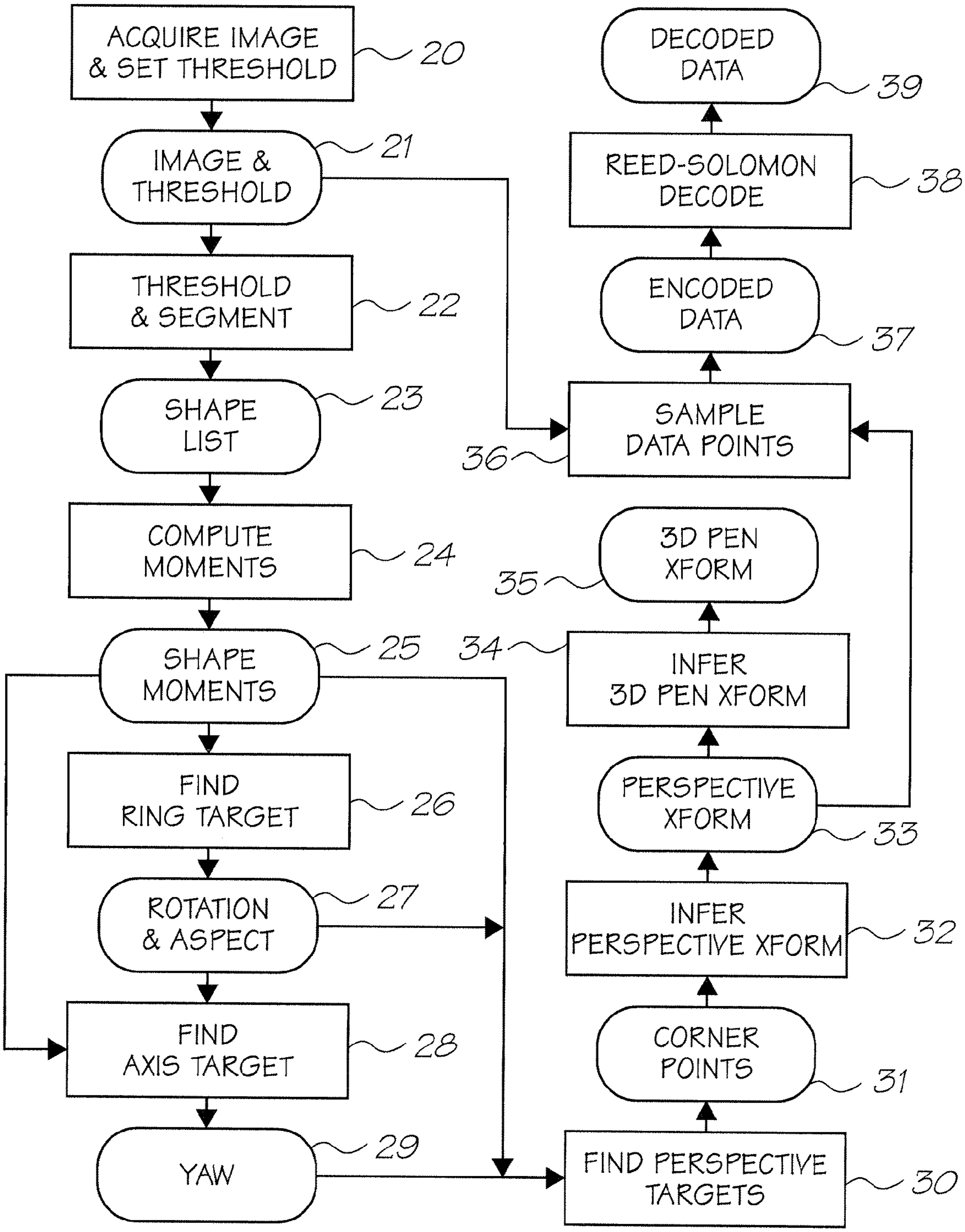

ACQUIRE IMAGE & SET THRESHOLD
20
IMAGE & THRESHOLD
21
THRESHOLD & SEGMENT
22
SHAPE LIST
23
COMPUTE MOMENTS
24
SHAPE MOMENTS
25
FIND RING TARGET
26
ROTATION & ASPECT
27
FIND AXIS TARGET
28
YAW
29
FIND PERSPECTIVE TARGETS
30
CORNER POINTS
31
INFER PERSPECTIVE XFORM
32
PERSPECTIVE XFORM
33
INFER 3D PEN XFORM
34
3D PEN XFORM
35
SAMPLE DATA POINTS
36
ENCODED DATA
37
REED-SOLOMON DECODE
38
DECODED DATA
39

FIG. 7

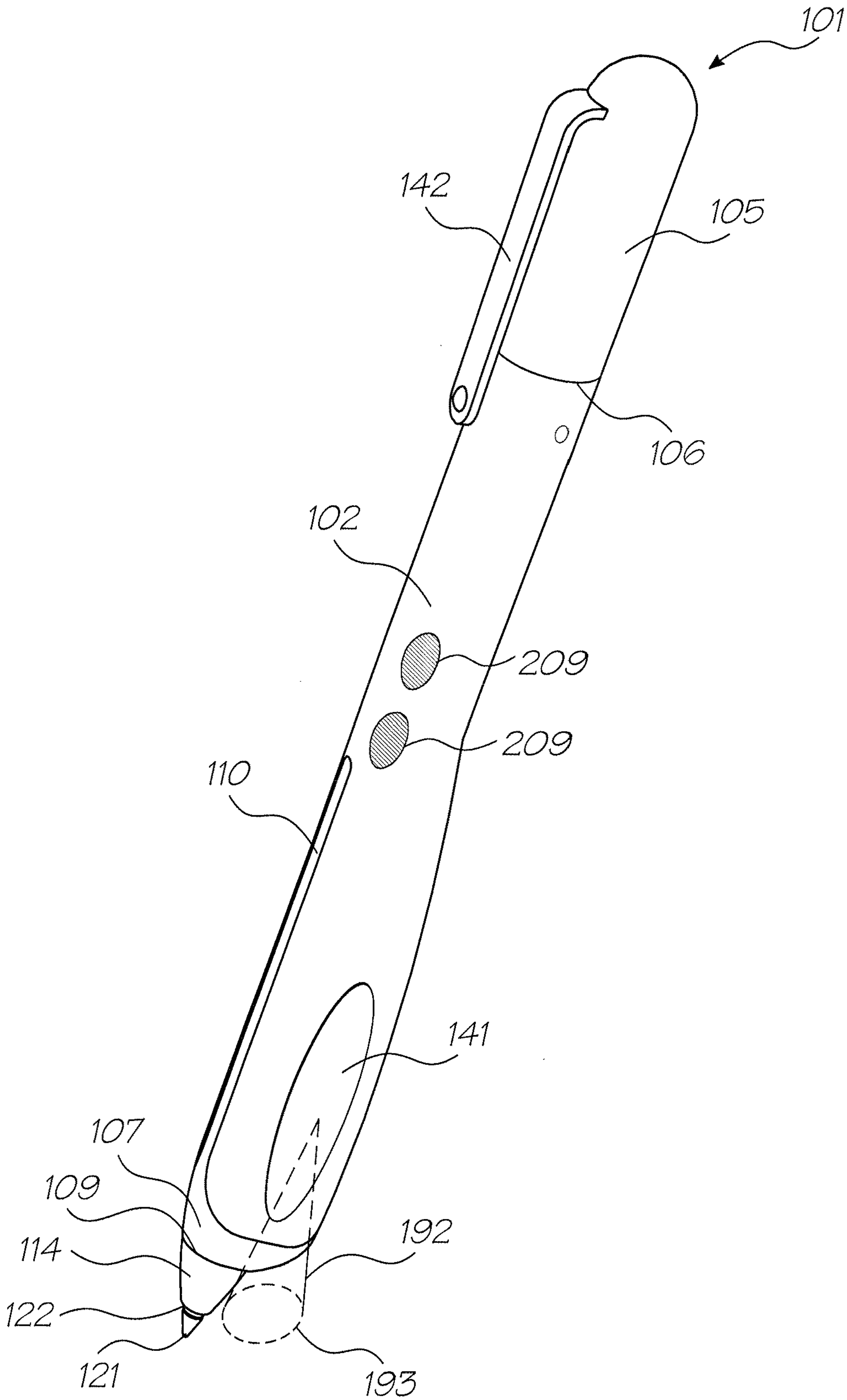


FIG. 8

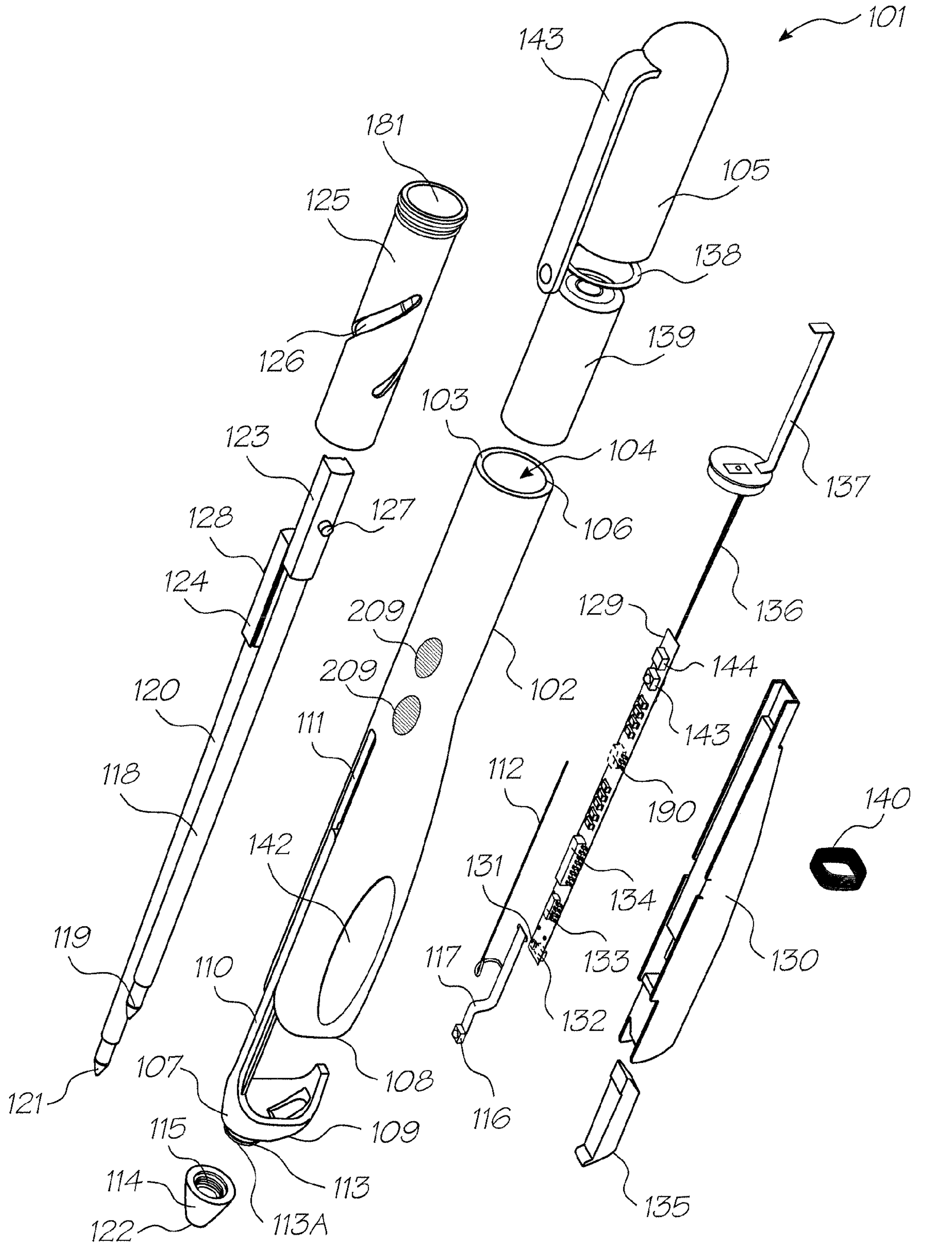
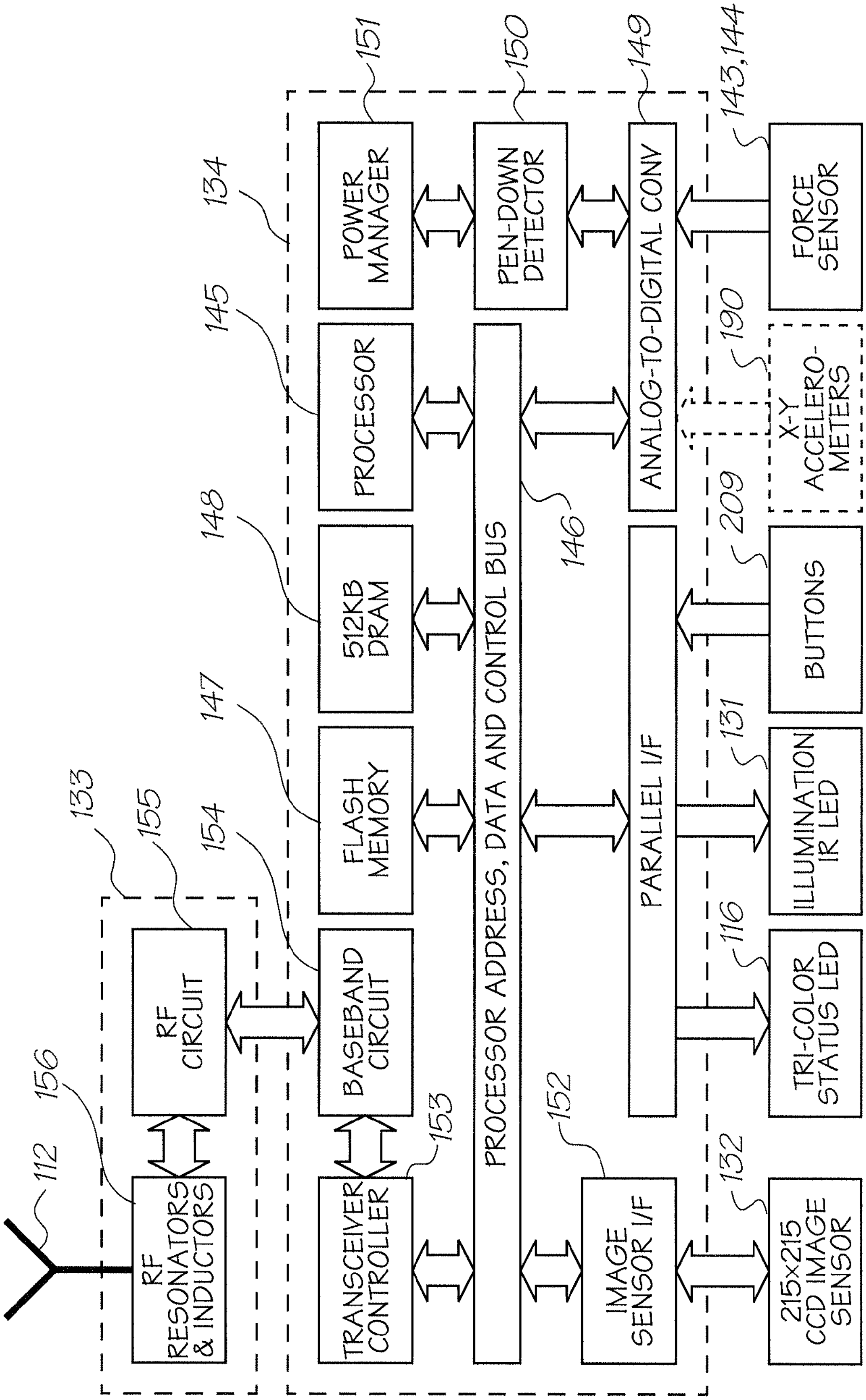

101
143
181
105
125
138
139
126
103
104
137
123
106
127
128
124
136
209
129
144
209
102
120
143
111
190
118
112
140
142
131
134
133
130
119
117
110
132
108
121
107
116
109
115
113
114
122
113A
135

FIG. 9



POWER MANAGER
PEN-DOWN DETECTOR
ANALOG-TO-DIGITAL CONV
FORCE SENSOR
PROCESSOR
X-Y ACCELERO-METERS
512KB DRAM
BUTTONS
FLASH MEMORY
ILLUMINATION IR LED
PARALLEL I/F
PROCESSOR ADDRESS, DATA AND CONTROL BUS
BASEBAND CIRCUIT
TRI-COLOR STATUS LED
RF CIRCUIT
RF RESONATORS & INDUCTORS
TRANSCEIVER CONTROLLER
IMAGE SENSOR I/F
215×215 CCD IMAGE SENSOR
151
150
149
143,144
134
145
190
148
146
209
147
131
133
155
154
116
156
153
152
112
132

FIG. 10

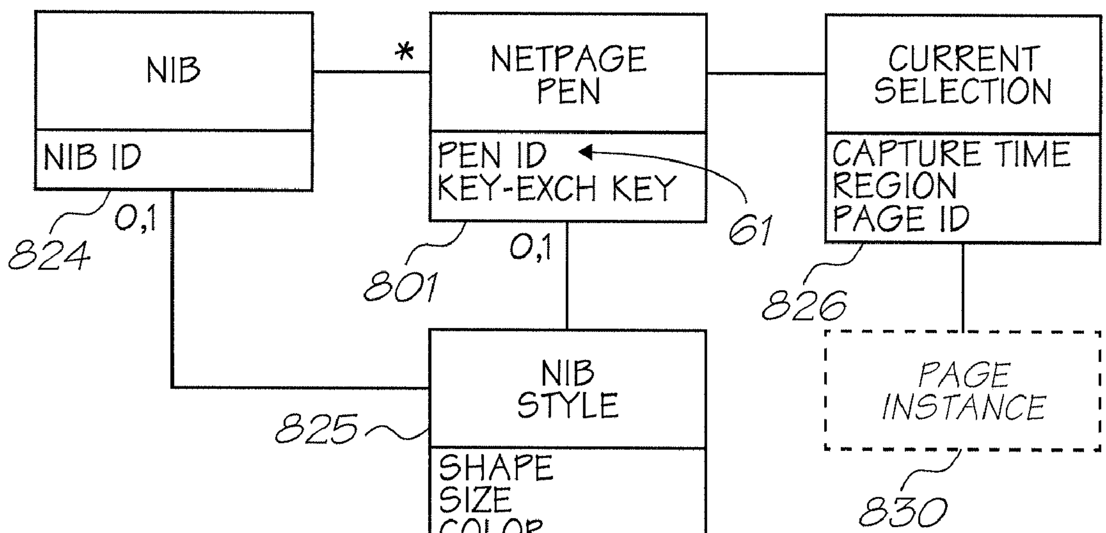

NIB
NIB ID
824
0,1
NETPAGE PEN
PEN ID
KEY-EXCH KEY
61
801
0,1
*
CURRENT SELECTION
CAPTURE TIME
REGION
PAGE ID
826
NIB STYLE
SHAPE
SIZE
COLOR
TEXTURE
825
PAGE INSTANCE
830

FIG. 11

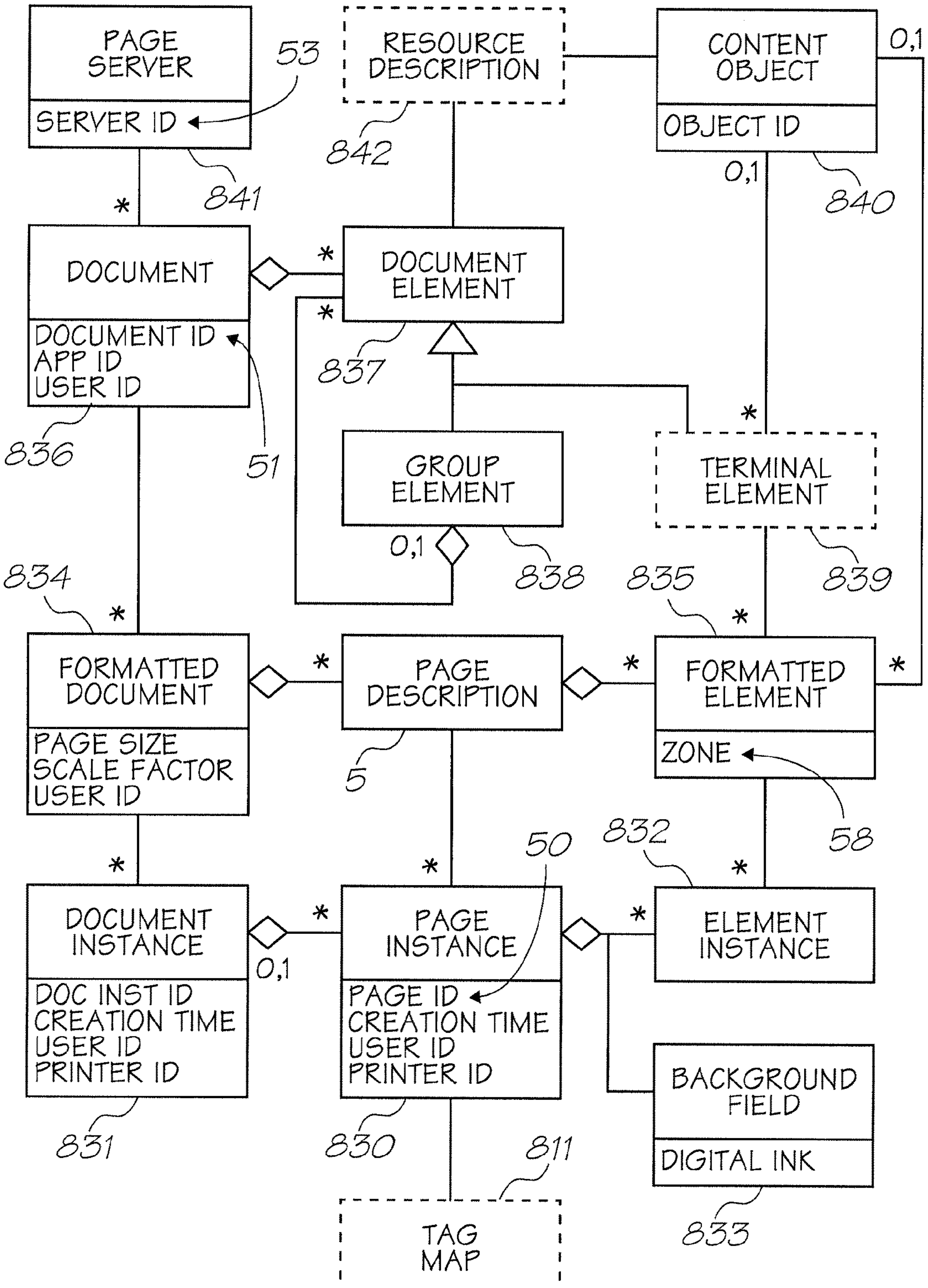
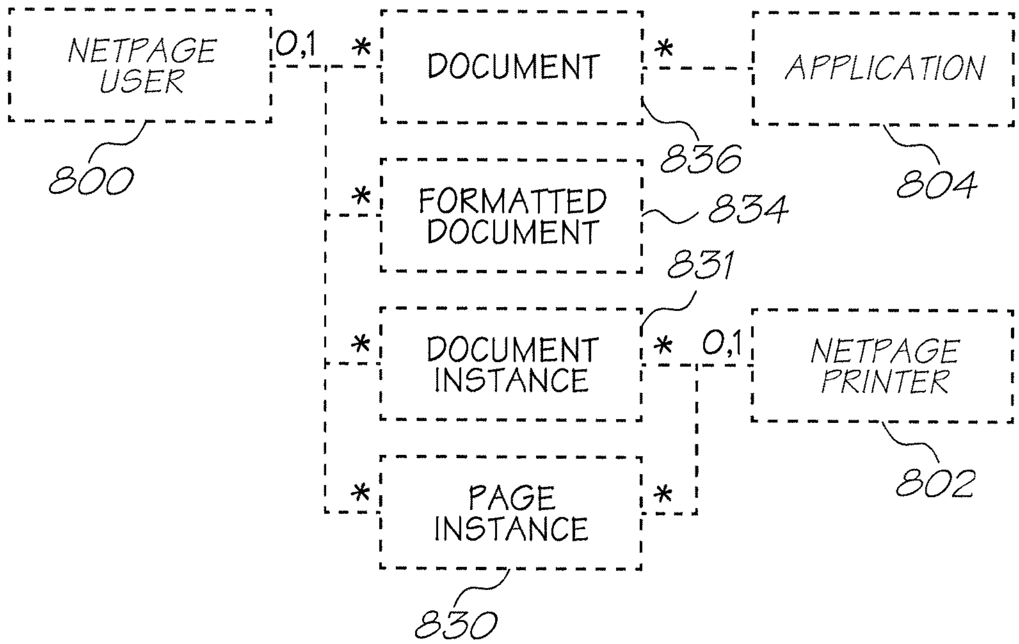
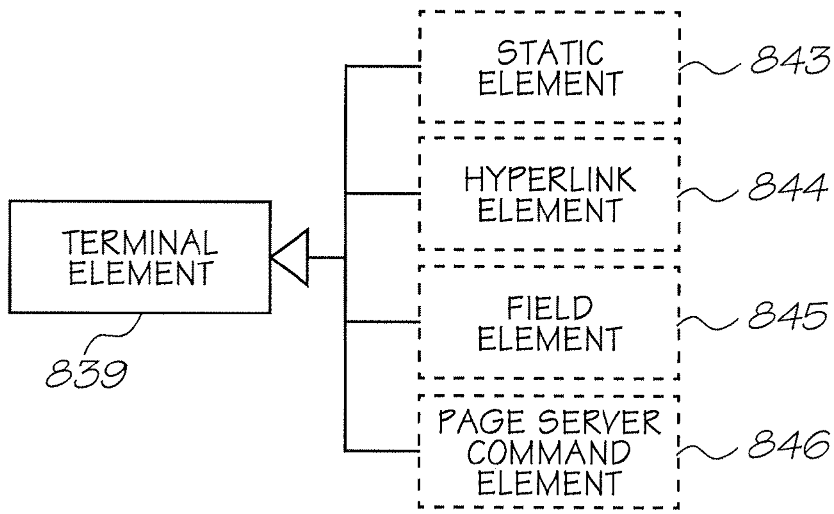

PAGE SERVER
SERVER ID
53
841
RESOURCE DESCRIPTION
842
CONTENT OBJECT
OBJECT ID
0,1
0,1
840
DOCUMENT
DOCUMENT ID
APP ID
USER ID
836
51
*
*
*
DOCUMENT ELEMENT
837
GROUP ELEMENT
0,1
838
TERMINAL ELEMENT
*
839
834
835
FORMATTED DOCUMENT
PAGE SIZE
SCALE FACTOR
USER ID
*
PAGE DESCRIPTION
5
*
FORMATTED ELEMENT
ZONE
*
58
DOCUMENT INSTANCE
DOC INST ID
CREATION TIME
USER ID
PRINTER ID
831
0,1
*
PAGE INSTANCE
PAGE ID
CREATION TIME
USER ID
PRINTER ID
830
50
832
ELEMENT INSTANCE
*
BACKGROUND FIELD
DIGITAL INK
833
811
TAG MAP

FIG. 12



NETPAGE USER
0,1
*
DOCUMENT
*
APPLICATION
800
836
804
*
FORMATTED DOCUMENT
834
831
*
DOCUMENT INSTANCE
*
0,1
NETPAGE PRINTER
802
*
PAGE INSTANCE
*
830

FIG. 13



STATIC ELEMENT
843
HYPERLINK ELEMENT
844
TERMINAL ELEMENT
FIELD ELEMENT
845
839
PAGE SERVER COMMAND ELEMENT
846

FIG. 14

METHOD OF SENSING MOTION OF A SENSING DEVICE RELATIVE TO A SURFACE

FIELD OF INVENTION

[0001] The present invention relates to a method and system for sensing a position-coding pattern on a surface. It has been developed primarily to improve the efficiency and accuracy of a motion-sensing device.

COPENDING

[0002] The following applications have been filed by the Applicant simultaneously with the present application:

[0003] NPZ026US NPZ027US NPZ028US NPZ029US NPZ030US NPZ031US

[0004] The disclosures of these co-pending applications are incorporated herein by reference. The above applications have been identified by their filing docket number, which will be substituted with the corresponding application number, once assigned.

CROSS REFERENCES

[0005] The following patents or patent applications filed by the applicant or assignee of the present invention are hereby incorporated by cross-reference.

6276850	6520631	6158907	6539180	6270177	6405055	6628430
6835135	6626529	6981769	7125338	7125337	7136186	7286260
7145689	7130075	7081974	7177055	7209257	6443555	7161715
7154632	7158258	7148993	7075684	10/943905	10/943906	10/943904
10/943903	10/943902	6966659	6988841	7077748	7255646	7070270
7014307	7158809	7217048	11/225172	11/255942	11/329039	11/329040
7271829	11/442189	11/474280	11/483061	11/503078	11/520735	11/505858
11/525850	11/583870	11/592983	11/592208	11/601828	11/635482	11/635526
10/466440	7215441	11/650545	11/653241	11/653240	7056040	6942334
11/706300	11/740265	11/737720	11/739056	11/740204	11/740223	11/753557
11/750285	11758648	11/778559	11834634	11/838878	11845669	6799853
7237896	6749301	10/451722	7137678	7252379	7144107	10/503900
10/503898	10/503897	7220068	7270410	7241005	7108437	7140792
10/503922	7224274	10/503917	10/503918	10/503925	10/503927	10/503928
10/503929	10/503885	7195325	7229164	7150523	10/503889	7154580
6906778	7167158	7128269	6688528	6986613	6641315	7278702
10/503891	7150524	7155395	6915140	6999206	6795651	6883910
7118481	7136198	7092130	6786661	6808325	10/920368	10/920284
7219990	10/920283	6750901	6476863	6788336	6322181	6597817
6227648	6727948	6690419	10/470947	6619654	6969145	6679582
10/470942	6568670	6866373	7280247	7008044	6742871	6966628
6644781	6969143	6767076	6834933	6692113	6913344	6727951
7128395	7036911	7032995	6969151	6955424	6969162	10/919249
6942315	11/006577	7234797	6986563	7295211	11/045442	7286162
7283159	7077330	6196541	11/149389	11/185725	7226144	11/202344
7267428	11/248423	11/248422	7093929	11/282769	11/330060	11/442111
7290862	11/499806	11/499710	6195150	11749156	11782588	11/854435
11/853817	11/935958	11924608	6362868	11970993	6831681	6431669
6362869	6472052	6356715	6894694	6636216	6366693	6329990
6459495	6137500	6690416	7050143	6398328	7110024	6431704
6879341	6415054	6665454	6542645	6486886	6381361	6317192
6850274	09/113054	6646757	6624848	6357135	6271931	6353772
6106147	6665008	6304291	6305770	6289262	6315200	6217165
6496654	6859225	6924835	6647369	6943830	09/693317	7021745
6712453	6460971	6428147	6416170	6402300	6464340	6612687
6412912	6447099	6837567	6505913	7128845	6733684	7249108
6566858	6331946	6246970	6442525	09/517384	09/505951	6374354
7246098	6816968	6757832	6334190	6745331	7249109	10/203559
7197642	7093139	10/636263	10/636283	10/866608	7210038	10/902883
10/940653	10/942858	11/706329	11/757385	11/758642	7119836	7283162
7286169	10/636285	7170652	6967750	6995876	7099051	7172191
7243916	7222845	11/239232	7285227	7063940	11/107942	7193734
7086724	7090337	7278723	7140717	11/190902	11/209711	7256824
7140726	7156512	7186499	11/478585	11/525862	11/540574	11/583875
11/592181	6750944	11/599336	7291447	11744183	11/758646	11/778561
11/839532	11/838874	11/853021	11/869710	11/868531	11927403	11951960
10/636225	6985207	6773874	6650836	10/666495	10/636224	7250975
7295343	6880929	7236188	7236187	7155394	10/636219	10/636223
7055927	6986562	7052103	7312845	10/656281	10/656791	10/666124
10/683217	7289142	7095533	6914686	6896252	6820871	6834851
6848686	6830246	6851671	10/729098	7092011	7187404	10/729159
10/753458	6878299	6929348	6921154	10/780625	10/804042	6913346
10/831238	10/831237	10/831239	10/831240	10/831241	10/831234	10/831233
7246897	7077515	10/831235	10/853336	10/853117	10/853659	10/853681
6913875	7021758	7033017	7161709	7099033	7147294	7156494
11/012024	11/011925	7032998	7044585	7296867	6994424	11/006787
7258435	7097263	7001012	7004568	7040738	7188933	7027080
7025446	6991321	7131715	7261392	7207647	7182435	7097285
11/228410	7097284	7083264	7147304	7232203	7156498	7201471

-continued

11/501772	11/503084	11/513073	7210764	11/635524	11/706379	11/730386
11/730784	11/753568	11/782591	11/859783	6710457	6775906	6507099
7221043	7107674	7154172	11/442400	7247941	11/736540	11/758644
11/940304	6530339	6631897	6851667	6830243	6860479	6997452
7000913	7204482	11/212759	11/281679	11/730409	6238044	6425661
11/003786	7258417	7293853	11/003334	7270395	11/003404	11/003419
11/003700	7255419	7284819	7229148	7258416	7273263	7270393
6984017	11/003699	11/071473	7156497	11/601670	11748482	11/778563
11/779851	11/778574	11/853816	11/853814	11/853786	11/872037	11/856694
11965703	11/003463	11/003701	11/003683	11/003614	7284820	11/003684
7246875	11/003617	11/764760	11853777	11955354	11/293800	11/293802
11/293801	11/293808	11/293809	11/482975	11/482970	11/482968	11/482972
11/482971	11/482969	6431777	6334664	6447113	7239407	6398359
6652089	6652090	7057759	6631986	7187470	7280235	11/501775
11744210	11/859784	6471331	6676250	6347864	6439704	6425700
6588952	6626515	6722758	6871937	11/060803	11/097266	11/097267
11/685084	11/685086	11/685090	11/740925	11/763444	11/763443	11946840
11961712	7249942	7206654	7162324	7162325	7231275	7146236
7278847	10/753499	6997698	7220112	7231276	10/753440	7220115
7195475	7144242	11/499746	11/501774	11/525858	11/545501	11/599335
11/706380	11736545	11/736554	11/739047	11749159	11/739073	11/775160
11/853755	11/940291	11934071	11951913	6786420	6827282	6948661
7073713	10/983060	7093762	7083108	7222799	7201319	11/442103
11/739071	11/518238	11/518280	11/518244	11/518243	11/518242	7032899
6854724	11/084237	11/084240	11/084238	11/357296	11/357298	11/357297
6350023	6318849	6592207	6439699	6312114	11/246676	11/246677
11/246678	11/246679	11/246680	11/246681	11/246714	11/246713	11/246689
11/246671	11/246670	11/246669	11/246704	11/246710	11/246688	11/246716
11/246715	11/246707	11/246706	11/246705	11/246708	11/246693	11/246692
11/246696	11/246695	11/246694	11/482958	11/482955	11/482962	11/482963
11/482956	11/482954	11/482974	11/482957	11/482987	11/482959	11/482960
11/482961	11/482964	11/482965	11/482976	11/482973	11/495815	11/495816
11/495817	60992635	60992637	60992641	10/803074	10/803073	7040823
10/803076	10/803077	10/803078	10/803079	10/922971	10/922970	10/922836
10/922842	10/922848	10/922843	7125185	7229226	11/513386	11/753559
10/815621	7243835	10/815630	10/815637	10/815638	7251050	10/815642
7097094	7137549	10/815618	7156292	11738974	10/815635	10/815647
10/815634	7137566	7131596	7128265	7207485	7197374	7175089
10/815617	10/815620	7178719	10/815613	7207483	7296737	7270266
10/815614	11/446240	11/488162	11/488163	11/488164	11/488167	11/488168
11/488165	11/488166	7267273	11/834628	11/839497	11/944449	10/815636
7128270	11/041650	11/041651	11/041652	11/041649	11/041610	11863253
11863255	11/863257	11863258	11863262	11/041609	11/041626	11/041627
11/041624	11/041625	11863268	11863269	11863270	11863271	11863273
76584733	11/041556	11/041580	11/041723	11/041698	11/041648	11863263
11863264	11863265	11863266	11863267	10/815609	7150398	7159777
10/815610	7188769	7097106	7070110	7243849	11/442381	11/480957
11/764694	11957470	6227652	6213588	6213589	6231163	6247795
6394581	6244691	6257704	6416168	6220694	6257705	6247794
6234610	6247793	6264306	6241342	6247792	6264307	6254220
6234611	6302528	6283582	6239821	6338547	6247796	6557977
6390603	6362843	6293653	6312107	6227653	6234609	6238040
6188415	6227654	6209989	6247791	6336710	6217153	6416167
6243113	6283581	6247790	6260953	6267469	6588882	6742873
6918655	6547371	6938989	6598964	6923526	6273544	6309048
6420196	6443558	6439689	6378989	6848181	6634735	6299289
6299290	6425654	6902255	6623101	6406129	6505916	6457809
6550895	6457812	7152962	6428133	7216956	7080895	11/144844
7182437	11/599341	11/635533	11/607976	11/607975	11/607999	11/607980
11/607979	11/607978	11/735961	11/685074	11/696126	11/696144	11/696650
11/763446	6224780	6235212	6280643	6284147	6214244	6071750
6267905	6251298	6258285	6225138	6241904	6299786	6866789
6231773	6190931	6248249	6290862	6241906	6565762	6241905
6451216	6231772	6274056	6290861	6248248	6306671	6331258
6110754	6294101	6416679	6264849	6254793	6245246	6855264
6235211	6491833	6264850	6258284	6312615	6228668	6180427
6171875	6267904	6245247	6315914	7169316	6526658	7210767
11/056146	11/635523	6665094	6450605	6512596	6654144	7125090
6687022	7072076	7092125	7215443	7136195	7077494	6877834
6969139	10/636227	7283280	6912067	7277205	7154637	10/636230
7070251	6851782	10/636211	10/636247	6843545	7079286	7064867
7065247	7027177	7218415	7064873	6954276	7061644	7092127
7059695	10/990382	7177052	7270394	11/124231	7188921	7187469
7196820	11/281445	7283281	7251051	7245399	11/524911	11/640267
11/706297	11/730387	11/737142	11/764729	11/834637	11/853019	11/863239
11/305274	11/305273	11/305275	11/305152	11/305158	11/305008	6231148

-continued

6293658	6614560	6238033	6312070	6238111	6378970	6196739
6270182	6152619	7006143	6876394	6738096	6970186	6287028
6412993	11/033145	11/102845	11/102861	11/248421	11/672878	7204941
7282164	10/815628	11845672	7278727	10/913373	10/913374	10/913372
7138391	7153956	10/913380	10/913379	10/913376	7122076	7148345
11/172816	11/172815	11/172814	11/482990	11/482986	11/482985	11/454899
11/583942	11/592990	11849360	11/831961	11/831962	11/831963	60951700
11/832629	11/832637	60971535	10/407212	7252366	10/683064	10/683041
7275811	10/884889	10/922890	10/922875	10/922885	10/922889	10/922884
10/922879	10/922887	10/922888	10/922874	7234795	10/922871	10/922880
7293855	10/922882	10/922883	10/922878	10/922872	10/922876	10/922886
10/922877	7147792	7175774	11/159193	11/491378	11766713	11/841647
11/482980	11/563684	11/482967	11/482966	11/482988	11/482989	11/293832
11/293838	11/293825	11/293841	11/293799	11/293796	11/293797	11/293798
11/124158	11/124196	11/124199	11/124162	11/124202	11/124197	11/124154
11/124198	7284921	11/124151	11/124160	11/124192	11/124175	11/124163
11/124149	11/124152	11/124173	11/124155	7236271	11/124174	11/124194
11/124164	11/124200	11/124195	11/124166	11/124150	11/124172	11/124165
11/124186	11/124185	11/124184	11/124182	11/124201	11/124171	11/124181
11/124161	11/124156	11/124191	11/124159	11/124176	11/124188	11/124170
11/124187	11/124189	11/124190	11/124180	11/124193	11/124183	11/124178
11/124177	11/124148	11/124168	11/124167	11/124179	11/124169	11/187976
11/188011	11/188014	11/482979	11/735490	11/853018	11/944450	11/228540
11/228500	11/228501	11/228530	11/228490	11/228531	11/228504	11/228533
11/228502	11/228507	11/228482	11/228505	11/228497	11/228487	11/228529
11/228484	11/228489	11/228518	11/228536	11/228496	11/228488	11/228506
11/228516	11/228526	11/228539	11/228538	11/228524	11/228523	11/228519
11/228528	11/228527	11/228525	11/228520	11/228498	11/228511	11/228522
11/228515	11/228537	11/228534	11/228491	11/228499	11/228509	11/228492
11/228493	11/228510	11/228508	11/228512	11/228514	11/228494	11/228495
11/228486	11/228481	11/228477	11/228485	11/228483	11/228521	11/228517
11/228532	11/228513	11/228503	11/228480	11/228535	11/228478	11/228479
6238115	6386535	6398344	6612240	6752549	6805049	6971313
6899480	6860664	6925935	6966636	7024995	7284852	6926455
7056038	6869172	7021843	6988845	6964533	6981809	7284822
7258067	11/155544	7222941	7284925	7278795	7249904	11/737726
11772240	11/863246	11/863145	11/865650	6087638	6340222	6041600
6299300	6067797	6286935	6044646	6382769	6787051	6938990
11/242916	11/144799	11/198235	11861282	11861284	11/766052	7152972
11/592996	D529952	6390605	6322195	6612110	6480089	6460778
6305788	6426014	6364453	6457795	6315399	6338548	7040736
6938992	6994425	6863379	6540319	6994421	6984019	7008043
6997544	6328431	6991310	10/965772	7140723	6328425	6982184
7267423	7134741	7066577	7152945	11/038200	7021744	6991320
7155911	11/107799	6595624	7152943	7125103	11/209709	7290857
7285437	7229151	11/330058	7237873	11/329163	11/442180	11/450431
7213907	6417757	11/482951	11/545566	11/583826	11/604315	11/604323
11/643845	11/706950	11/730399	11749121	11/753549	11/834630	11/935389
11/869670	7095309	11/945157	11957473	11967235	6854825	6623106
6672707	6575561	6817700	6588885	7075677	6428139	6575549
6846692	6425971	7063993	6383833	6955414	6412908	6746105
6953236	6412904	7128388	6398343	6652071	6793323	6659590
6676245	7201460	6464332	6659593	6478406	6978613	6439693
6502306	6966111	6863369	6428142	6874868	6390591	6799828
6896358	7018016	10/296534	6328417	6322194	6382779	6629745
6565193	6609786	6609787	6439908	6684503	6843551	6764166
6561617	10/510092	6557970	6546628	10/510098	6652074	6820968
7175260	6682174	7303262	6648453	6834932	6682176	6998062
6767077	7278717	6755509	10/534813	6692108	10/534811	6672709
7303263	7086718	10/534881	6672710	10/534812	6669334	10/534804
7152958	7281782	6824246	7264336	6669333	10/534815	6820967
7306326	6736489	7264335	6719406	7222943	7188419	7168166
6974209	7086719	6974210	7195338	7252775	7101025	11/474281
11/485258	11/706304	11/706324	11/706326	11/706321	11/772239	11/782598
11/829941	11/852991	11852986	11/936062	11/934027	11955028	11/763440
11/763442	11/246687	11/246718	11/246685	11/246686	11/246703	11/246691
11/246711	11/246690	11/246712	11/246717	11/246709	11/246700	11/246701
11/246702	11/246668	11/246697	11/246698	11/246699	11/246675	11/246674
11/246667	11/829957	11/829960	11/829961	11/829962	11/829963	11/829966
11/829967	11/829968	11/829969	11946839	11946838	11946837	11951230
7156508	7159972	7083271	7165834	7080894	7201469	7090336
7156489	10/760233	10/760246	7083257	7258422	7255423	7219980
10/760253	10/760255	10/760209	7118192	10/760194	10/760238	7077505
7198354	7077504	10/760189	7198355	10/760232	10/760231	7152959
7213906	7178901	7222938	7108353	7104629	11/446227	11/454904
11/472345	11/474273	7261401	11/474279	11/482939	11/482950	11/499709

-continued

7306324	7306325	11/603824	11/601756	11/601672	7303261	11/653253
11/706328	11/706299	11/706965	11/737080	11/737041	11/778062	11/778566
11/782593	11/934018	11/945157	11951095	11951828	11954906	11954949
11967226	7303930	11/246672	11/246673	11/246683	11/246682	60/939086
11860538	11860539	11/860540	11860541	11860542	11/936060	11877667
11877668	7246886	7128400	7108355	6991322	7287836	7118197
10/728784	10/728783	7077493	6962402	10/728803	7147308	10/728779
7118198	7168790	7172270	7229155	6830318	7195342	7175261
10/773183	7108356	7118202	10/773186	7134744	10/773185	7134743
7182439	7210768	10/773187	7134745	7156484	7118201	7111926
10/773184	7018021	11/060751	11/060805	11/188017	7128402	11/298774
11/329157	11/490041	11/501767	7284839	7246885	7229156	11/505846
11/505857	7293858	11/524908	11/524938	7258427	11/524912	7278716
11/592995	11/603825	11/649773	11/650549	11/653237	11/706378	11/706962
11749118	11/754937	11749120	11/744885	11/779850	11/765439	11/842950
11/839539	11/926121	11/097308	11/097309	7246876	11/097299	11/097310
11/097213	11/210687	11/097212	7147306	7261394	11/764806	11/782595
11965696	11/482953	11/482977	11/544778	11/544779	11/764808	11/756624
11/756625	11/756626	11/756627	11/756628	11/756629	11/756630	11/756631
7156289	7178718	7225979	11/712434	11/084796	11/084742	11/084806
09/575197	7079712	6825945	09/575165	6813039	7190474	6987506
6824044	7038797	6980318	6816274	7102772	09/575186	6681045
6678499	6679420	6963845	6976220	6728000	7110126	7173722
6976035	6813558	6766942	6965454	6995859	7088459	6720985
7286113	6922779	6978019	6847883	7131058	7295839	09/607843
09/693690	6959298	6973450	7150404	6965882	7233924	09/575181
09/722174	7175079	7162259	6718061	10/291523	10/291471	7012710
6825956	10/291481	7222098	10/291825	7263508	7031010	6972864
6862105	7009738	6989911	6982807	10/291576	6829387	6714678
6644545	6609653	6651879	10/291555	7293240	10/291592	10/291542
7044363	7004390	6867880	7034953	6987581	7216224	10/291821
7162269	7162222	7290210	7293233	7293234	6850931	6865570
6847961	10/685523	10/685583	7162442	10/685584	7159784	10/804034
10/793933	6889896	10/831232	7174056	6996274	7162088	10/943874
10/943872	10/944044	7259884	10/944043	7167270	10/943877	6986459
10/954170	7181448	10/981626	10/981616	10/981627	7231293	7174329
10/992713	7295922	7200591	11/020106	11/020260	11/020321	11/020319
11/026045	11/059696	11/051032	11/059674	11/107944	11/107941	11/082940
11/082815	11/082827	11/082829	6991153	6991154	11/124256	11/123136
11/154676	11/159196	11/182002	11/202251	11/202252	11/202253	11/203200
11/202218	11/206778	11/203424	11/222977	11/228450	11/227239	11/286334
7225402	11/329187	11/349143	11/491225	11/491121	11/442428	11/454902
11/442385	11/478590	7271931	11/520170	11/603057	11/706964	11/739032
11739014	11/834633	11/830848	11/830849	11/839542	11/866394	11/934077
11951874	7068382	7007851	6957921	6457883	10/743671	7044381
11/203205	7094910	7091344	7122685	7038066	7099019	7062651
6789194	6789191	10/900129	7278018	10/913350	10/982975	10/983029
11/331109	6644642	6502614	6622999	6669385	6827116	7011128
10/949307	6549935	6987573	6727996	6591884	6439706	6760119
7295332	7064851	6826547	6290349	6428155	6785016	6831682
6741871	6927871	6980306	6965439	6840606	7036918	6977746
6970264	7068389	7093991	7190491	10/901154	10/932044	10/962412
7177054	10/962552	10/965733	10/965933	10/974742	10/982974	7180609
10/986375	11/107817	7292363	11/149160	11/206756	11/250465	7202959
11/653219	11/706309	11/730389	11/730392	60/953443	11/866387	60974077
6982798	6870966	6822639	6474888	6627870	6724374	6788982
7263270	6788293	6946672	6737591	7091960	09/693514	6792165
7105753	6795593	6980704	6768821	7132612	7041916	6797895
7015901	7289882	7148644	10/778056	10/778058	10/778060	10/778059
10/778063	10/778062	10/778061	10/778057	7096199	7286887	10/917467
10/917466	10/917465	7218978	7245294	7277085	7187370	10/917436
10/943856	10/919379	7019319	10/943878	10/943849	7043096	7148499
11/144840	11/155556	11/155557	11/193481	11/193435	11/193482	11/193479
11/255941	11/281671	11/298474	7245760	11/488832	11/495814	11/495823
11/495822	11/495821	11/495820	11/653242	11/754370	60911260	11/829936
11/839494	11866305	11866313	11866324	11866336	11866348	11866359
11970951	7055739	7233320	6830196	6832717	7182247	7120853
7082562	6843420	10/291718	6789731	7057608	6766944	6766945
7289103	10/291559	7299969	7264173	10/409864	7108192	10/537159
7111791	7077333	6983878	10/786631	7134598	10/893372	6929186
6994264	7017826	7014123	7134601	7150396	10/971146	7017823
7025276	7284701	7080780	11/074802	11/442366	11749158	11/842948
10/492169	10/492152	10/492168	10/492161	7308148	10/502575	10/531229
10/683151	10/531733	10/683040	10/510391	10/919260	10/510392	10/778090
11/944404	11/936638	6957768	09/575172	7170499	7106888	7123239
6982701	6982703	7227527	6786397	6947027	6975299	7139431

-continued

7048178	7118025	6839053	7015900	7010147	7133557	6914593
10/291546	6938826	7278566	7123245	6992662	7190346	11/074800
11/074782	11/074777	11/075917	7221781	11/102843	7213756	11/188016
7180507	7263225	7287688	11/737094	11/753570	11/782596	11/865711
11856061	11856062	11856064	11856066	11/672522	11/672950	11/672947
11/672891	11/672954	11/672533	11754310	11/754321	11/754320	11/754319
11/754318	11/754317	11/754316	11/754315	11/754314	11/754313	11/754312
11/754311	6593166	7132679	6940088	7119357	7307272	6755513
6974204	6409323	7055930	6281912	6893109	6604810	6824242
6318920	7210867	6488422	6655786	6457810	6485135	6796731
6904678	6641253	7125106	6786658	7097273	6824245	7222947
6918649	6860581	6929351	7063404	6969150	7004652	6871938
6905194	6846059	6997626	10/974881	7029098	6966625	7114794
7207646	7077496	7284831	11/072529	7152938	7182434	7182430
11/102842	7032993	11/155513	11/155545	11/144813	7172266	7258430
7128392	7210866	11/488066	11/505933	11/540727	11/635480	11/707946
11/706303	11/709084	11/730776	11/744143	11/779845	11/782589	11/863256
11/940302	11/940235	11955359	11/066161	11/066160	11/066159	11/066158
7287831	11/875936	6804030	6807315	6771811	6683996	7271936
7304771	6965691	7058219	7289681	7187807	7181063	11/338783
11/603823	11/650536	10/727181	10/727162	10/727163	10/727245	7121639
7165824	7152942	10/727157	7181572	7096137	7302592	7278034
7188282	10/727159	10/727180	10/727179	10/727192	10/727274	10/727164
10/727161	10/727198	10/727158	10/754536	10/754938	10/727227	10/727160
10/934720	7171323	7278697	11/442131	11/474278	11/488853	11/488841
11749750	11749749	11955127	11951213	10/296522	6795215	7070098
7154638	6805419	6859289	6977751	6398332	6394573	6622923
6747760	6921144	10/884881	7092112	7192106	11/039866	7173739
6986560	7008033	11/148237	7222780	7270391	7150510	11/478599
11/499749	11/521388	11/738518	11/482981	11/743662	11/743661	11/743659
11/743655	11/743657	11/752900	11926109	11927163	11929567	7195328
7182422	11/650537	11/712540	10/854521	10/854522	10/854488	7281330
10/854503	10/854504	10/854509	7188928	7093989	10/854497	10/854495
10/854498	10/854511	10/854512	10/854525	10/854526	10/854516	7252353
10/854515	7267417	10/854505	10/854493	7275805	7314261	10/854490
7281777	7290852	10/854528	10/854523	10/854527	10/854524	10/854520
10/854514	10/854519	10/854513	10/854499	10/854501	7266661	7243193
10/854518	10/854517	10/934628	7163345	11/499803	11/601757	11/706295
11/735881	11748483	11749123	11/766061	11775135	11772235	11/778569
11/829942	11/870342	11/935274	11/937239	11961907	11961940	11961961
11/014731	D529081	D541848	D528597	6924907	6712452	6416160
6238043	6958826	6812972	6553459	6967741	6956669	6903766
6804026	7259889	6975429	10/636234	10/636233	7301567	10/636216
7274485	7139084	7173735	7068394	7286182	7086644	7250977
7146281	7023567	7136183	7083254	6796651	7061643	7057758
6894810	6995871	7085010	7092126	7123382	7061650	10/853143
6986573	6974212	7307756	7173737	10/954168	7246868	11/065357
7137699	11/107798	7148994	7077497	11/176372	7248376	11/225158
11/225154	7173729	11/442132	11/478607	11/503085	11/545502	11/583943
11/585946	11/653239	11/653238	11/764781	11/764782	11/779884	11845666
11/872637	11/944401	11/940215	11/544764	11/544765	11/544772	11/544773
11/544774	11/544775	11/544776	11/544766	11/544767	11/544771	11/544770
11/544769	11/544777	11/544768	11/544763	11/293804	11/293840	11/293803
11/293833	11/293834	11/293835	11/293836	11/293837	11/293792	11/293794
11/293839	11/293826	11/293829	11/293830	11/293827	11/293828	7270494
11/293823	11/293824	11/293831	11/293815	11/293819	11/293818	11/293817
11/293816	11/838875	11/482978	11/640356	11/640357	11/640358	11/640359
11/640360	11/640355	11/679786	11/872714	10/760254	10/760210	10/760202
7201468	10/760198	10/760249	7234802	7303255	7287846	7156511
10/760264	7258432	7097291	10/760222	10/760248	7083273	10/760192
10/760203	10/760204	10/760205	10/760206	10/760267	10/760270	7198352
10/760271	7303251	7201470	7121655	7293861	7232208	10/760186
10/760261	7083272	7261400	11/474272	11/474315	7311387	11/583874
7303258	11/706322	11/706968	11/749119	11749157	11779848	11/782590
11/855152	11855151	11/870327	11/934780	11/935992	11951193	11/014764
11/014763	11/014748	11/014747	11/014761	11/014760	11/014757	7303252
7249822	11/014762	11/014724	11/014723	11/014756	11/014736	11/014759
11/014758	11/014725	11/014739	11/014738	11/014737	11/014726	11/014745
11/014712	7270405	7303268	11/014735	11/014734	11/014719	11/014750
11/014749	7249833	11/758640	11/775143	11/838877	11944453	11/944633
11955065	11/014769	11/014729	11/014743	11/014733	7300140	11/014755
11/014765	11/014766	11/014740	7284816	7284845	7255430	11/014744
11/014741	11/014768	11/014767	11/014718	11/014717	11/014716	11/014732
11/014742	11/097268	11/097185	11/097184	11/778567	11852958	11852907
11/872038	11955093	11961578	11/293820	11/293813	11/293822	11/293812
11/293821	11/293814	11/293793	11/293842	11/293811	11/293807	11/293806

-continued

11/293805	11/293810	11/688863	11/688864	11/688865	11/688866	11/688867
11/688868	11/688869	11/688871	11/688872	11/688873	11/741766	11/482982
11/482983	11/482984	11/495818	11/495819	11/677049	11/677050	11/677051
11872719	11872718	11/014722	11/934781	D528156	10/760180	7111935
10/760213	10/760219	10/760237	7261482	10/760220	7002664	10/760252
10/760265	7088420	11/446233	11/503083	11/503081	11/516487	11/599312
6364451	6533390	6454378	7224478	6559969	6896362	7057760
6982799	11/202107	11/743672	11744126	11/743673	7093494	7143652
7089797	7159467	7234357	7124643	7121145	7089790	7194901
6968744	7089798	7240560	7137302	11/442177	7171855	7260995
7260993	7165460	7222538	7258019	11/543047	7258020	11/604324
11/642520	11/706305	11/707056	11744211	11/767526	11/779846	11/764227
11/829943	11/829944	6454482	6808330	6527365	6474773	6550997
7093923	6957923	7131724	10/949288	7168867	7125098	11/706966
11/185722	7249901	7188930	11/014728	11/014727	D536031	D531214
7237888	7168654	7201272	6991098	7217051	6944970	10/760215
7108434	10/760257	7210407	7186042	10/760266	6920704	7217049
10/760214	10/760260	7147102	7287828	7249838	10/760241	10/962413
10/962427	7261477	7225739	10/962402	10/962425	10/962428	7191978
10/962426	10/962409	10/962417	10/962403	7163287	7258415	10/962523
7258424	10/962410	7195412	7207670	7270401	7220072	11/474267
11/544547	11/585925	11/593000	11/706298	11/706296	11/706327	11/730760
11/730407	11/730787	11/735977	11/736527	11/753566	11/754359	11/778061
11/765398	11/778556	11/829937	11/780470	11/866399	11/223262	11/223018
11/223114	11955366	11/223022	11/223021	11/223020	11/223019	11/014730
D541849	29/279123	6716666	6949217	6750083	7014451	6777259
6923524	6557978	6991207	6766998	6967354	6759723	6870259
10/853270	6925875	10/898214	7095109	7145696	10/976081	7193482
7134739	7222939	7164501	7118186	7201523	7226159	7249839
7108343	7154626	7079292	10/980184	7233421	7063408	10/983082
10/982804	7032996	10/982834	10/982833	10/982817	7217046	6948870
7195336	7070257	10/986813	10/986785	7093922	6988789	10/986788
7246871	10/992748	10/992747	7187468	10/992828	7196814	10/992754
7268911	7265869	7128384	7164505	7284805	7025434	7298519
7280244	7206098	7265877	7193743	7168777	11/006734	7195329
7198346	7281786	11/013363	11/013881	6959983	7128386	7097104
11/013636	7083261	7070258	7083275	7110139	6994419	6935725
11/026046	7178892	7219429	6988784	11/026135	7289156	11/064005
7284976	7178903	7273274	7083256	11/064008	7278707	11/064013
6974206	11/064004	7066588	7222940	11/075918	7018025	7221867
7290863	7188938	7021742	7083262	7192119	11/083021	7036912
7175256	7182441	7083258	7114796	7147302	11/084757	7219982
7118195	7229153	6991318	7108346	11/248429	11/239031	7178899
7066579	11/281419	11/298633	11/329188	11/329140	7270397	7258425
7237874	7152961	11/478592	7207658	11/484744	7311257	7207659
11/525857	11/540569	11/583869	11/592985	11/585947	7306307	11/604316
11/604309	11/604303	11/643844	11/650553	11/655940	11/653320	7278713
11/706381	11/706323	11/706963	11/713660	7290853	11/696186	11/730390
11/737139	11/737749	11/740273	11749122	11/754361	11766043	11/764775
11/768872	11/775156	11/779271	11/779272	11/829938	11/839502	11858852
11/862188	11859790	11/872618	11/923651	11950255	11930001	11955362
11965718	6485123	6425657	6488358	7021746	6712986	6981757
6505912	6439694	6364461	6378990	6425658	6488361	6814429
6471336	6457813	6540331	6454396	6464325	6443559	6435664
6412914	6488360	6550896	6439695	6447100	09/900160	6488359
6637873	10/485738	6618117	10/485737	6803989	7234801	7044589
7163273	6416154	6547364	10/485744	6644771	7152939	6565181
10/485805	6857719	7255414	6702417	7284843	6918654	7070265
6616271	6652078	6503408	6607263	7111924	6623108	6698867
6488362	6625874	6921153	7198356	6536874	6425651	6435667
10/509997	6527374	10/510154	6582059	10/510152	6513908	7246883
6540332	6547368	7070256	6508546	10/510151	6679584	10/510000
6857724	10/509998	6652052	10/509999	6672706	10/510096	6688719
6712924	6588886	7077508	7207654	6935724	6927786	6988787
6899415	6672708	6644767	6874866	6830316	6994420	6954254
7086720	7240992	7267424	7128397	7084951	7156496	7066578
7101023	11/165027	11/202235	11/225157	7159965	7255424	11/349519
7137686	7201472	7287829	11/504602	7216957	11/520572	11/583858
11/583895	11/585976	11/635488	7278712	11/706952	11/706307	7287827
11944451	11/740287	11/754367	11/758643	11/778572	11859791	11/863260
11/874178	11/936064	11951983	6916082	6786570	10/753478	6848780
6966633	7179395	6969153	6979075	7132056	6832828	6860590
6905620	6786574	6824252	7097282	6997545	6971734	6918652
6978990	6863105	10/780624	7194629	10/791792	6890059	6988785
6830315	7246881	7125102	7028474	7066575	6986202	7044584
7210762	7032992	7140720	7207656	7285170	11/048748	7008041

-continued

7011390	7048868	7014785	7131717	7284826	11/176158	7182436
7104631	7240993	7290859	11/202217	7172265	7284837	7066573
11/298635	7152949	11/442161	11/442133	11/442126	7156492	11/478588
11/505848	7287834	11/525861	11/583939	11/545504	7284326	11/635485
11/730391	11/730788	11/749148	11/749149	11/749152	11/749151	11/759886
11/865668	11/874168	11/874203	11965722	6824257	7270475	6971811
6878564	6921145	6890052	7021747	6929345	6811242	6916087
6905195	6899416	6883906	6955428	7284834	6932459	6962410
7033008	6962409	7013641	7204580	7032997	6998278	7004563
6910755	6969142	6938994	7188935	10/959049	7134740	6997537
7004567	6916091	7077588	6918707	6923583	6953295	6921221
7001008	7168167	7210759	11/008115	11/011120	11/012329	6988790
7192120	7168789	7004577	7052120	11/123007	6994426	7258418
7014298	11/124348	11/177394	7152955	7097292	7207657	7152944
7147303	11/209712	7134608	7264333	7093921	7077590	7147297
11/239029	11/248832	11/248428	11/248434	7077507	7172672	7175776
7086717	7101020	11/329155	7201466	11/330057	7152967	7182431
7210666	7252367	7287837	11/485255	11/525860	6945630	7018294
6910014	6659447	6648321	7082980	6672584	7073551	6830395
7289727	7001011	6880922	6886915	6644787	6641255	7066580
6652082	7284833	6666544	6666543	6669332	6984023	6733104
6644793	6723575	6953235	6663225	7076872	7059706	7185971
7090335	6854827	6793974	10/636258	7222929	6739701	7073881
7155823	7219427	7008503	6783216	6883890	6857726	10/636274
6641256	6808253	6827428	6802587	6997534	6959982	6959981
6886917	6969473	6827425	7007859	6802594	6792754	6860107
6786043	6863378	7052114	7001007	10/729151	10/729157	6948794
6805435	6733116	10/683006	7008046	6880918	7066574	6983595
6923527	7275800	7163276	7156495	6976751	6994430	7014296
7059704	7160743	7175775	7287839	7097283	7140722	11/123009
11/123008	7080893	7093920	7270492	7128093	7052113	7055934
11/155627	7278796	11/159197	7083263	7145592	7025436	11/281444
7258421	11/478591	11/478735	7226147	11/482940	7195339	11/503061
11/505938	7284838	7293856	11/544577	11/540576	11/585964	11/592991
11/599342	11/600803	11/604321	11/604302	11/635535	11/635486	11/643842
11/655987	11/650541	11/706301	11/707039	11/730388	11/730786	11/730785
11/739080	11/764746	11/768875	11/779847	11/829940	11847240	11/834625
11/863210	11/865680	11/874156	11/923602	11951940	11954988	11961662
7067067	6776476	6880914	7086709	6783217	7147791	6929352
7144095	6820974	6918647	6984016	7192125	6824251	6834939
6840600	6786573	7144519	6799835	6959975	6959974	7021740
6935718	6938983	6938991	7226145	7140719	6988788	7022250
6929350	7011393	7004566	7175097	6948799	7143944	7310157
7029100	6957811	7073724	7055933	7077490	7055940	10/991402
7234645	7032999	7066576	7229150	7086728	7246879	7284825
7140718	7284817	7144098	7044577	7284824	7284827	7189334
7055935	7152860	11/203188	11/203173	11/202343	7213989	11/225156
11/225173	7300141	7114868	7168796	7159967	11/272425	7152805
11/298530	11/330061	7133799	11/330054	11/329284	7152956	7128399
7147305	7287702	11/442160	7246884	7152960	11/442125	11/454901
11/442134	11/450441	11/474274	11/499741	7270399	6857728	6857729
6857730	6989292	7126216	6977189	6982189	7173332	7026176
6979599	6812062	6886751	10/804057	10/804036	7001793	6866369
6946743	10/804048	6886918	7059720	10/846561	10/846562	10/846647
10/846649	10/846627	6951390	6981765	6789881	6802592	7029097
6799836	7048352	7182267	7025279	6857571	6817539	6830198
6992791	7038809	6980323	7148992	7139091	6947173	7101034
6969144	6942319	6827427	6984021	6984022	6869167	6918542
7007852	6899420	6918665	6997625	6988840	6984080	6845978
6848687	6840512	6863365	7204582	6921150	7128396	6913347
7008819	6935736	6991317	7284836	7055947	7093928	7100834
7270396	7187086	7290856	7032825	7086721	7159968	7010456
7147307	7111925	11/144812	7229154	11/505849	11/520570	11/520575
11/546437	11/540575	11/583937	7278711	7290720	11/592207	11/635489
11/604319	11/635490	11/635525	7287706	11/706366	11/706310	11/706308
11/785108	11/744214	11744218	11748485	11/748490	11/764778	11/766025
11/834635	11839541	11860420	11/865693	11/863118	11/866307	11/866340
11/869684	11/869722	11/869694	11/876592	11/945244	11951121	11/945238
11955358	11965710	11962050				

BACKGROUND

[0006] The Applicant has previously described a method of enabling users to access information from a computer system via a printed substrate e.g. paper. The substrate has coded data printed thereon, which is read by an optical sensing device when the user interacts with the substrate using the sensing device. A computer receives interaction data from the sensing device and uses this data to determine what action is being requested by the user. For example, a user may make handwritten input onto a form or make a selection gesture around a printed item. This input is interpreted by the computer system with reference to a page description corresponding to the printed substrate.

[0007] It would be desirable to improve the efficiency and accuracy of motion sensing by the sensing device. Efficiency improvements enable the sensing device to consume less power and increase its lifetime between charges or battery replacement. Accuracy improvements are desirable at, for example, high sampling rates when the sensing device may be unable to capture sufficient number of images of the coded data due to inherent limitations in its design.

SUMMARY OF INVENTION

[0008] In a first aspect the present invention provides a method of sensing motion of a sensing device relative to a surface, the method including the steps of:

[0009] optically imaging a position-coding pattern disposed on or in the surface;

[0010] independently sensing relative position changes of the sensing device using a motion sensor;

[0011] generating absolute motion data by determining a plurality of absolute positions of the sensing device relative to the surface using the imaged position-coding pattern;

[0012] independently generating relative motion data using the relative position changes sensed by the motion sensor; and

[0013] determining the motion of the sensing device using the absolute motion data supplemented with the relative motion data.

Optionally, an extent to which the relative motion data supplements the absolute motion data is dependent on at least one of:

- **[0014]** a sampling rate of imaging the position-coding pattern;
- **[0015]** a speed of movement of the sensing device relative to the surface; and power-saving criteria for the sensing device.

Optionally, the motion sensor is selected from any one of the group comprising: at least one accelerometer; a mechanical mouse; an optical mouse; and a point interferometry device.

Optionally, said motion sensor is an optical mouse utilizing at least one of: a pattern-based optical mouse technique; a texture-based optical mouse technique; and a laser-speckle-based optical mouse technique.

Optionally, the absolute motion data comprises a plurality of sensed absolute positions, the relative motion data comprises a plurality of sensed relative position changes, and wherein the method includes the further step of:

[0016] combining the sensed relative position changes with the sensed absolute positions to generate additional absolute positions.

Optionally, the combining step comprises at least one of:

[0017] adding the sensed relative position changes to the sensed absolute positions; and

[0018] substracting the sensed relative position changes from the sensed absolute positions.

Optionally, neighbouring absolute positions, as sensed over time, are interleaved with at least one relative position change.

Optionally, the position-coding pattern is indicative of a plurality of locations on the surface and of an identity of a region.

In a further aspect the method further comprising the step of:

[0019] determining the identity of the region using the imaged position-coding pattern.

Optionally, the identity of the region is coincident with an identity of the surface.

Optionally, the position-coding pattern is comprised of a plurality of tags, each tag identifying the identity of the surface and a location of the tag on the surface.

In a further aspect the method further comprising the step of:

[0020] transmitting data indicative of the motion of the sensing device to a computer system, thereby enabling the computer system to interpret said motion and initiate an action corresponding to said motion.

In a second aspect the present invention provides a sensing device configured for determining its own motion relative to a surface, said sensing device comprising:

[0021] a first motion sensor comprising:

- **[0022]** an image sensor for imaging a position-coding pattern on the surface; and
- **[0023]** a first processor configured for generating absolute motion data by determining a plurality of absolute positions of the sensing device relative to the surface using the imaged position-coding pattern;

[0024] a second motion sensor configured for independently generating relative motion data by determining one or more relative position changes of the sensing device; and

[0025] a second processor configured for determining the motion of the sensing device using the absolute motion data supplemented with the relative motion data.

Optionally, the first and second processors are the same processor.

Optionally, the second processor is configured such that an extent to which the relative motion data supplements the absolute motion data is dependent on at least one of:

- **[0026]** a sampling rate of imaging the position-coding pattern;
- **[0027]** a speed of movement of the sensing device relative to the surface; and
- **[0028]** power-saving criteria for the sensing device.

Optionally, the second motion sensor is selected from any one of the group comprising: at least one accelerometer; a mechanical mouse; an optical mouse; and a point interferometry device.

Optionally, said second motion sensor is an optical mouse utilizing at least one of: a pattern-based optical mouse technique; a texture-based optical mouse technique; and a laser-speckle-based optical mouse technique.

Optionally, said second motion sensor is an optical mouse comprising the image sensor.

In a further aspect the present invention provides a sensing device further comprising communication means for transmitting data indicative of the motion of the sensing device to a computer system, thereby enabling the computer system to interpret said motion and initiate an action corresponding to said motion.

In a third aspect the present invention provides a system for initiating an action corresponding to motion of a sensing device relative to a surface, said system comprising:

(A) the sensing device comprising:

[0029] a first motion sensor comprising:

- **[0030]** an image sensor for imaging a position-coding pattern on the surface; and
- **[0031]** a first processor configured for generating absolute motion data by determining a plurality of absolute

positions of the sensing device relative to the surface using the imaged position-coding pattern;

[0032] a second motion sensor configured for generating relative motion data by determining one or more relative position changes of the sensing device, said second motion sensor being operatively independent of said first motion sensor;

[0033] a second processor configured for determining the motion of the sensing device using the absolute motion data supplemented with the relative motion data; and

[0034] communication means for communicating data indicative of the motion of the sensing device to a computer system; and

(B) the computer system configured for:

[0035] receiving the data indicative of the motion of the sensing device;

[0036] interpreting said motion; and

[0037] initiating an action corresponding to the motion of the sensing device.

BRIEF DESCRIPTION OF DRAWINGS

[0038] Preferred and other embodiments of the invention will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

[0039] FIG. **1** shows an embodiment of basic netpage architecture;

[0040] FIG. **2** is a schematic of a the relationship between a sample printed netpage and its online page description;

[0041] FIG. **3** shows an embodiment of basic netpage architecture with various alternatives for the relay device;

[0042] FIG. **3**A illustrates a collection of netpage servers, Web terminals, printers and relays interconnected via a network;

[0043] FIG. **4** is a schematic view of a high-level structure of a printed netpage and its online page description;

[0044] FIG. **5**A is a plan view showing a structure of a netpage tag;

[0045] FIG. **5**B is a plan view showing a relationship between a set of the tags shown in FIG. **5***a* and a field of view of a netpage sensing device in the form of a netpage pen;

[0046] FIG. **6**A is a plan view showing an alternative structure of a netpage tag;

[0047] FIG. **6**B is a plan view showing a relationship between a set of the tags shown in FIG. **6***a* and a field of view of a netpage sensing device in the form of a netpage pen;

[0048] FIG. **6**C is a plan view showing an arrangement of nine of the tags shown in FIG. **6***a* where targets are shared between adjacent tags;

[0049] FIG. **6**D is a plan view showing the interleaving and rotation of the symbols of the four codewords of the tag shown in FIG. **6***a;*

[0050] FIG. **7** is a flowchart of a tag image processing and decoding algorithm;

[0051] FIG. **8** is a perspective view of a netpage pen and its associated tag-sensing field-of-view cone;

[0052] FIG. **9** is a perspective exploded view of the netpage pen shown in FIG. **8**;

[0053] FIG. **10** is a schematic block diagram of a pen controller for the netpage pen shown in FIGS. **8** and **9**;

[0054] FIG. **11** is a schematic view of a pen class diagram;

[0055] FIG. **12** is a schematic view of a document and page description class diagram;

[0056] FIG. **13** is a schematic view of a document and page ownership class diagram; and

[0057] FIG. **14** is a schematic view of a terminal element specialization class diagram.

DETAILED DESCRIPTION OF PREFERRED AND OTHER EMBODIMENTS

[0058] Note: Memjet™ is a trade mark of Silverbrook Research Pty Ltd, Australia.

[0059] In the preferred embodiment, the invention is configured to work with the netpage networked computer system, a detailed overview of which follows. It will be appreciated that not every implementation will necessarily embody all or even most of the specific details and extensions discussed below in relation to the basic system. However, the system is described in its most complete form to reduce the need for external reference when attempting to understand the context in which the preferred embodiments and aspects of the present invention operate.

[0060] In brief summary, the preferred form of the netpage system employs a computer interface in the form of a mapped surface, that is, a physical surface which contains references to a map of the surface maintained in a computer system. The map references can be queried by an appropriate sensing device. Depending upon the specific implementation, the map references may be encoded visibly or invisibly, and defined in such a way that a local query on the mapped surface yields an unambiguous map reference both within the map and among different maps. The computer system can contain information about features on the mapped surface, and such information can be retrieved based on map references supplied by a sensing device used with the mapped surface. The information thus retrieved can take the form of actions which are initiated by the computer system on behalf of the operator in response to the operator's interaction with the surface features.

[0061] In its preferred form, the netpage system relies on the production of, and human interaction with, netpages. These are pages of text, graphics and images printed on ordinary paper, but which work like interactive webpages. Information is encoded on each page using ink which is substantially invisible to the unaided human eye. The ink, however, and thereby the coded data, can be sensed by an optically imaging sensing device and transmitted to the netpage system. The sensing device may take the form of a clicker (for clicking on a specific position on a surface), a pointer having a stylus (for pointing or gesturing on a surface using pointer strokes), or a pen having a marking nib (for marking a surface with ink when pointing, gesturing or writing on the surface). References herein to "pen" or "netpage pen" are provided by way of example only. It will, of course, be appreciated that the pen may take the form of any of the sensing devices described above.

[0062] In one embodiment, active buttons and hyperlinks on each page can be clicked with the sensing device to request information from the network or to signal preferences to a network server. In one embodiment, text written by hand on a netpage is automatically recognized and converted to computer text in the netpage system, allowing forms to be filled in. In other embodiments, signatures recorded on a netpage are automatically verified, allowing e-commerce transactions to be securely authorized. In other embodiments, text on a netpage may be clicked or gestured to initiate a search based on keywords indicated by the user.

[0063] As illustrated in FIG. **2**, a printed netpage **1** can represent a interactive form which can be filled in by the user both physically, on the printed page, and "electronically", via communication between the pen and the netpage system. The example shows a "Request" form containing name and address fields and a submit button. The netpage consists of graphic data **2** printed using visible ink, and coded data **3** printed as a collection of tags **4** using invisible ink. The corresponding page description **5**, stored on the netpage network, describes the individual elements of the netpage. In particular it describes the type and spatial extent (zone) of each interactive element (i.e. text field or button in the example), to allow the netpage system to correctly interpret input via the netpage. The submit button **6**, for example, has a zone **7** which corresponds to the spatial extent of the corresponding graphic **8**.

[0064] As illustrated in FIGS. **1** and **3**, a netpage sensing device **101**, such as the pen shown in FIGS. **8** and **9** and described in more detail below, works in conjunction with a netpage relay device **601**, which is an Internet-connected device for home, office or mobile use. The pen is wireless and communicates securely with the netpage relay device **601** via a short-range radio link **9**. In an alternative embodiment, the netpage pen **101** utilises a wired connection, such as a USB or other serial connection, to the relay device **601**.

[0065] The relay device **601** performs the basic function of relaying interaction data to a page server **10**, which interprets the interaction data. As shown in FIG. **3**, the relay device **601** may, for example, take the form of a personal computer **601***a*, a netpage printer **601***b* or some other relay **601***c*.

[0066] The netpage printer **601***b* is able to deliver, periodically or on demand, personalized newspapers, magazines, catalogs, brochures and other publications, all printed at high quality as interactive netpages. Unlike a personal computer, the netpage printer is an appliance which can be, for example, wall-mounted adjacent to an area where the morning news is first consumed, such as in a user's kitchen, near a breakfast table, or near the household's point of departure for the day. It also comes in tabletop, desktop, portable and miniature versions. Netpages printed on-demand at their point of consumption combine the ease-of-use of paper with the timeliness and interactivity of an interactive medium.

[0067] Alternatively, the netpage relay device **601** may be a portable device, such as a mobile phone or PDA, a laptop or desktop computer, or an information appliance connected to a shared display, such as a TV. If the relay device **601** is not a netpage printer **601***b* which prints netpages digitally and on demand, the netpages may be printed by traditional analog printing presses, using such techniques as offset lithography, flexography, screen printing, relief printing and rotogravure, as well as by digital printing presses, using techniques such as drop-on-demand inkjet, continuous inkjet, dye transfer, and laser printing.

[0068] As shown in FIG. **3**, the netpage sensing device **101** interacts with the coded data on a printed netpage **1**, or other printed substrate such as a label of a product item **251**, and communicates, via a short-range radio link **9**, the interaction to the relay **601**. The relay **601** sends corresponding interaction data to the relevant netpage page server **10** for interpretation. Raw data received from the sensing device **101** may be relayed directly to the page server **10** as interaction data. Alternatively, the interaction data may be encoded in the form of an interaction URI and transmitted to the page server **10** via a user's web browser. Of course, the relay device **601** (e.g. mobile phone) may incorporate a web browser and a display device.

[0069] Interpretation of the interaction data by the page server **10** may result in direct access to information requested by the user. This information may be sent from the page server **10** to, for example, a user's display device (e.g. a display device associated with the relay device **601**). The information sent to the user may be in the form of a webpage constructed by the page server **10** and the webpage may be constructed using information from external web services **200** (e.g. search engines) or local web resources accessible by the page server **10**. In some circumstances, the page server **10** may access application computer software running on a netpage application server **13**.

[0070] Alternatively, and as shown explicitly in FIG. **1**, a two-step information retrieval process may be employed. Interaction data is sent from the sensing device **101** to the relay device **601** in the usual way. The relay device **601** then sends the interaction data to the page server **10** for interpretation with reference to the relevant page description **5**. Then, the page server **10** forms a request (typically in the form of a request URI) and sends this request URI back to the user's relay device **601**. A web browser running on the relay device **601** then sends the request URI to a netpage web server **201**, which interprets the request. The netpage web server **201** may interact with local web resources and external web services **200** to interpret the request and construct a webpage. Once the webpage has been constructed by the netpage web server **201**, it is transmitted to the web browser running on the user's relay device **601**, which typically displays the webpage. This system architecture is particularly useful for performing searching via netpages, as described in our earlier U.S. patent application Ser. No. 11/672,950 filed on Feb. 8, 2007 (the contents of which is incorporated by reference). For example, the request URI may encode search query terms, which are searched via the netpage web server **201**.

[0071] The netpage relay device **601** can be configured to support any number of sensing devices, and a sensing device can work with any number of netpage relays. In the preferred implementation, each netpage sensing device **101** has a unique identifier. This allows each user to maintain a distinct profile with respect to a netpage page server **10** or application server **13**.

[0072] Digital, on-demand delivery of netpages **1** may be performed by the netpage printer **601***b*, which exploits the growing availability of broadband Internet access. Netpage publication servers **14** on the netpage network are configured to deliver print-quality publications to netpage printers. Periodical publications are delivered automatically to subscribing netpage printers via pointcasting and multicasting Internet protocols. Personalized publications are filtered and formatted according to individual user profiles.

[0073] A netpage pen may be registered with a netpage registration server **11** and linked to one or more payment card accounts. This allows e-commerce payments to be securely authorized using the netpage pen. The netpage registration server compares the signature captured by the netpage pen with a previously registered signature, allowing it to authenticate the user's identity to an e-commerce server. Other biometrics can also be used to verify identity. One version of the netpage pen includes fingerprint scanning, verified in a similar way by the netpage registration server.

Netpage System Architecture

[0074] Each object model in the system is described using a Unified Modeling Language (UML) class diagram. A class diagram consists of a set of object classes connected by relationships, and two kinds of relationships are of interest here: associations and generalizations. An association represents some kind of relationship between objects, i.e. between instances of classes. A generalization relates actual classes, and can be understood in the following way: if a class is thought of as the set of all objects of that class, and class A is a generalization of class B, then B is simply a subset of A. The UML does not directly support second-order modelling—i.e. classes of classes.

[0075] Each class is drawn as a rectangle labelled with the name of the class. It contains a list of the attributes of the class, separated from the name by a horizontal line, and a list of the operations of the class, separated from the attribute list by a horizontal line. In the class diagrams which follow, however, operations are never modelled.

[0076] An association is drawn as a line joining two classes, optionally labelled at either end with the multiplicity of the association. The default multiplicity is one. An asterisk (*) indicates a multiplicity of "many", i.e. zero or more. Each association is optionally labelled with its name, and is also optionally labelled at either end with the role of the corresponding class. An open diamond indicates an aggregation association ("is-part-of"), and is drawn at the aggregator end of the association line.

[0077] A generalization relationship ("is-a") is drawn as a solid line joining two classes, with an arrow (in the form of an open triangle) at the generalization end.

[0078] When a class diagram is broken up into multiple diagrams, any class which is duplicated is shown with a dashed outline in all but the main diagram which defines it. It is shown with attributes only where it is defined.

1 Netpages

[0079] Netpages are the foundation on which a netpage network is built. They provide a paper-based user interface to published information and interactive services.

[0080] A netpage consists of a printed page (or other surface region) invisibly tagged with references to an online description of the page. The online page description is maintained persistently by the netpage page server **10**. The page description describes the visible layout and content of the page, including text, graphics and images. It also describes the input elements on the page, including buttons, hyperlinks, and input fields. A netpage allows markings made with a netpage pen on its surface to be simultaneously captured and processed by the netpage system.

[0081] Multiple netpages (for example, those printed by analog printing presses) can share the same page description. However, to allow input through otherwise identical pages to be distinguished, each netpage may be assigned a unique page identifier. This page ID has sufficient precision to distinguish between a very large number of netpages.

[0082] Each reference to the page description is encoded in a printed tag. The tag identifies the unique page on which it appears, and thereby indirectly identifies the page description. The tag also identifies its own position on the page. Characteristics of the tags are described in more detail below.

[0083] Tags are typically printed in infrared-absorptive ink on any substrate which is infrared-reflective, such as ordinary paper, or in infrared fluorescing ink. Near-infrared wavelengths are invisible to the human eye but are easily sensed by a solid-state image sensor with an appropriate filter.

[0084] A tag is sensed by a 2D area image sensor in the netpage sensing device, and the tag data is transmitted to the netpage system via the nearest netpage relay device. The pen is wireless and communicates with the netpage relay device via a short-range radio link. Tags are sufficiently small and densely arranged that the sensing device can reliably image at least one tag even on a single click on the page. It is important that the pen recognize the page ID and position on every interaction with the page, since the interaction is stateless. Tags are error-correctably encoded to make them partially tolerant to surface damage.

[0085] The netpage page server **10** maintains a unique page instance for each unique printed netpage, allowing it to maintain a distinct set of user-supplied values for input fields in the page description for each printed netpage.

[0086] The relationship between the page description, the page instance, and the printed netpage is shown in FIG. **4**. The printed netpage may be part of a printed netpage document **45**. The page instance may be associated with both the netpage printer which printed it and, if known, the netpage user who requested it.

2 Netpage Tags

2.1 Tag Data Content

[0087] In a preferred form, each tag identifies the region in which it appears, and the location of that tag within the region and an orientation of the tag relative to a substrate on which the tag is printed. A tag may also contain flags which relate to the region as a whole or to the tag. One or more flag bits may, for example, signal a tag sensing device to provide feedback indicative of a function associated with the immediate area of the tag, without the sensing device having to refer to a description of the region. A netpage pen may, for example, illuminate an "active area" LED when in the zone of a hyperlink.

[0088] As will be more clearly explained below, in a preferred embodiment, each tag typically contains an easily recognized invariant structure which aids initial detection, and which assists in minimizing the effect of any warp induced by the surface or by the sensing process. The tags preferably tile the entire page, and are sufficiently small and densely arranged that the pen can reliably image at least one tag even on a single click on the page. It is important that the pen recognize the page ID and position on every interaction with the page, since the interaction is stateless.

[0089] In a preferred embodiment, the region to which a tag refers coincides with an entire page, and the region ID encoded in the tag is therefore synonymous with the page ID of the page on which the tag appears. In other embodiments, the region to which a tag refers can be an arbitrary subregion of a page or other surface. For example, it can coincide with the zone of an interactive element in which case the region ID can directly identify the interactive element.

TABLE 1

Tag data

Field	Precision (bits)
Page ID/Region ID	100
Tag ID/x-y coordinates	16
Flags	4
Total	120

[0090] Each tag contains 120 bits of information, typically allocated as shown in Table 1. Assuming a maximum tag density of 64 per square inch, a 16-bit tag ID supports a region size of up to 1024 square inches. Larger regions can be mapped continuously without increasing the tag ID precision simply by using abutting regions and maps. The 100-bit region ID allows 2^{100} (~10^{30} or a million trillion trillion) different regions to be uniquely identified.

2.2 Tag Data Encoding

[0091] The 120 bits of tag data are redundantly encoded using a (15, 5) Reed-Solomon code. This yields **360** encoded bits consisting of 6 codewords of 15 4-bit symbols each. The (15, 5) code allows up to 5 symbol errors to be corrected per codeword, i.e. it is tolerant of a symbol error rate of up to 33% per codeword.

[0092] Each 4-bit symbol is represented in a spatially coherent way in the tag, and the symbols of the six codewords are interleaved spatially within the tag. This ensures that a burst error (an error affecting multiple spatially adjacent bits) damages a minimum number of symbols overall and a minimum number of symbols in any one codeword, thus maximising the likelihood that the burst error can be fully corrected.

[0093] Any suitable error-correcting code can be used in place of a (15, 5) Reed-Solomon code, for example a Reed-Solomon code with more or less redundancy, with the same or different symbol and codeword sizes; another block code; or a different kind of code, such as a convolutional code (see, for example, Stephen B. Wicker, Error Control Systems for Digital Communication and Storage, Prentice-Hall 1995, the contents of which a herein incorporated by cross-reference).

2.3 Physical Tag Structure

[0094] The physical representation of the tag, shown in FIG. **5***a*, includes fixed target structures **15**, **16**, **17** and variable data areas **18**. The fixed target structures allow a sensing device such as the netpage pen to detect the tag and infer its three-dimensional orientation relative to the sensor. The data areas contain representations of the individual bits of the encoded tag data.

[0095] To achieve proper tag reproduction, the tag is rendered at a resolution of 256×256 dots. When printed at 1600 dots per inch this yields a tag with a diameter of about 4 mm. At this resolution the tag is designed to be surrounded by a "quiet area" of radius 16 dots. Since the quiet area is also contributed by adjacent tags, it only adds 16 dots to the effective diameter of the tag.

[0096] The tag may include a plurality of target structures. A detection ring **15** allows the sensing device to initially detect the tag. The ring is easy to detect because it is rotationally invariant and because a simple correction of its aspect ratio removes most of the effects of perspective distortion. An orientation axis **16** allows the sensing device to determine the approximate planar orientation of the tag due to the yaw of the sensor. The orientation axis is skewed to yield a unique orientation. Four perspective targets **17** allow the sensing device to infer an accurate two-dimensional perspective transform of the tag and hence an accurate three-dimensional position and orientation of the tag relative to the sensor.

[0097] All target structures are redundantly large to improve their immunity to noise.

[0098] In order to support "single-click" interaction with a tagged region via a sensing device, the sensing device must be able to see at least one entire tag in its field of view no matter where in the region or at what orientation it is positioned. The required diameter of the field of view of the sensing device is therefore a function of the size and spacing of the tags.

[0099] Thus, if a tag has a circular shape, the minimum diameter of the sensor field of view is obtained when the tags are tiled on a equilateral triangular grid, as shown in FIG. **5***b*.

2.4 Tag Image Processing and Decoding

[0100] The tag image processing and decoding performed by a sensing device such as the netpage pen is shown in FIG. **7**. While a captured image is being acquired from the image sensor, the dynamic range of the image is determined (at **20**). The center of the range is then chosen as the binary threshold for the image **21**. The image is then thresholded and segmented into connected pixel regions (i.e. shapes **23**) (at **22**). Shapes which are too small to represent tag target structures are discarded. The size and centroid of each shape is also computed.

[0101] Binary shape moments **25** are then computed (at **24**) for each shape, and these provide the basis for subsequently locating target structures. Central shape moments are by their nature invariant of position, and can be easily made invariant of scale, aspect ratio and rotation.

[0102] The ring target structure **15** is the first to be located (at **26**). A ring has the advantage of being very well behaved when perspective-distorted. Matching proceeds by aspect-normalizing and rotation-normalizing each shape's moments. Once its second-order moments are normalized the ring is easy to recognize even if the perspective distortion was significant. The ring's original aspect and rotation **27** together provide a useful approximation of the perspective transform.

[0103] The axis target structure **16** is the next to be located (at **28**). Matching proceeds by applying the ring's normalizations to each shape's moments, and rotation-normalizing the resulting moments. Once its second-order moments are normalized the axis target is easily recognized. Note that one third order moment is required to disambiguate the two possible orientations of the axis. The shape is deliberately skewed to one side to make this possible. Note also that it is only possible to rotation-normalize the axis target after it has had the ring's normalizations applied, since the perspective distortion can hide the axis target's axis. The axis target's original rotation provides a useful approximation of the tag's rotation due to pen yaw **29**.

[0104] The four perspective target structures **17** are the last to be located (at **30**). Good estimates of their positions are computed based on their known spatial relationships to the ring and axis targets, the aspect and rotation of the ring, and the rotation of the axis. Matching proceeds by applying the ring's normalizations to each shape's moments. Once their second-order moments are normalized the circular perspective targets are easy to recognize, and the target closest to each estimated position is taken as a match. The original centroids of the four perspective targets are then taken to be the perspective-distorted corners **31** of a square of known size in tag space, and an eight-degree-of-freedom perspective transform **33** is inferred (at **32**) based on solving the well-understood equations relating the four tag-space and image-space point pairs (see Heckbert, P., Fundamentals of Texture Mapping and Image Warping, Masters Thesis, Dept. of EECS, U. of

California at Berkeley, Technical Report No. UCB/CSD 89/516, June 1989, the contents of which are herein incorporated by cross-reference).

[0105] The inferred tag-space to image-space perspective transform is used to project (at **36**) each known data bit position in tag space into image space where the real-valued position is used to bilinearly interpolate (at **36**) the four relevant adjacent pixels in the input image. The previously computed image threshold **21** is used to threshold the result to produce the final bit value **37**.

[0106] Once all 360 data bits **37** have been obtained in this way, each of the six 60-bit Reed-Solomon codewords is decoded (at **38**) to yield **20** decoded bits **39**, or **120** decoded bits in total. Note that the codeword symbols are sampled in codeword order, so that codewords are implicitly de-interleaved during the sampling process.

[0107] The ring target **15** is only sought in a subarea of the image whose relationship to the image guarantees that the ring, if found, is part of a complete tag. If a complete tag is not found and successfully decoded, then no pen position is recorded for the current frame. Given adequate processing power and ideally a non-minimal field of view **193**, an alternative strategy involves seeking another tag in the current image.

[0108] The obtained tag data indicates the identity of the region containing the tag and the position of the tag within the region. An accurate position **35** of the pen nib in the region, as well as the overall orientation **35** of the pen, is then inferred (at **34**) from the perspective transform **33** observed on the tag and the known spatial relationship between the image sensor (containing the optical axis of the pen) and the nib (which typically contains the physical axis of the pen). The image sensor is usually offset from the nib.

2.5 Alternative Tag Structures

[0109] The tag structure described above is designed to support the tagging of non-planar surfaces where a regular tiling of tags may not be possible. In the more usual case of planar surfaces where a regular tiling of tags is possible, i.e. surfaces such as sheets of paper and the like, more efficient tag structures can be used which exploit the regular nature of the tiling.

[0110] FIG. **6*a*** shows a square tag **4** with four perspective targets **17**. The tag represents sixty 4-bit Reed-Solomon symbols **47**, for a total of 240 bits. The tag represents each one bit as a dot **48**, and each zero bit by the absence of the corresponding dot. The perspective targets are designed to be shared between adjacent tags, as shown in FIGS. **6*b*** and **6*c***. FIG. **6*b*** shows a square tiling of 16 tags and the corresponding minimum field of view **193**, which must span the diagonals of two tags. FIG. **6*c*** shows a square tiling of nine tags, containing all one bits for illustration purposes.

[0111] Using a (15, 7) Reed-Solomon code, 112 bits of tag data are redundantly encoded to produce 240 encoded bits. The four codewords are interleaved spatially within the tag to maximize resilience to burst errors. Assuming a 16-bit tag ID as before, this allows a region ID of up to 92 bits.

[0112] The data-bearing dots **48** of the tag are designed to not overlap their neighbors, so that groups of tags cannot produce structures which resemble targets. This also saves ink. The perspective targets therefore allow detection of the tag, so further targets are not required. Tag image processing proceeds as described in section 1.2.4 above, with the exception that steps **26** and **28** are omitted.

[0113] Although the tag may contain an orientation feature to allow disambiguation of the four possible orientations of the tag relative to the sensor, it is also possible to embed orientation data in the tag data. For example, the four codewords can be arranged so that each tag orientation contains one codeword placed at that orientation, as shown in FIG. **6*d***, where each symbol is labelled with the number of its codeword (1-4) and the position of the symbol within the codeword (A-O). Tag decoding then consists of decoding one codeword at each orientation. Each codeword can either contain a single bit indicating whether it is the first codeword, or two bits indicating which codeword it is. The latter approach has the advantage that if, say, the data content of only one codeword is required, then at most two codewords need to be decoded to obtain the desired data. This may be the case if the region ID is not expected to change within a stroke and is thus only decoded at the start of a stroke. Within a stroke only the codeword containing the tag ID is then desired. Furthermore, since the rotation of the sensing device changes slowly and predictably within a stroke, only one codeword typically needs to be decoded per frame.

[0114] It is possible to dispense with perspective targets altogether and instead rely on the data representation being self-registering. In this case each bit value (or multi-bit value) is typically represented by an explicit glyph, i.e. no bit value is represented by the absence of a glyph. This ensures that the data grid is well-populated, and thus allows the grid to be reliably identified and its perspective distortion detected and subsequently corrected during data sampling. To allow tag boundaries to be detected, each tag data must contain a marker pattern, and these must be redundantly encoded to allow reliable detection. The overhead of such marker patterns is similar to the overhead of explicit perspective targets.

[0115] Additional tag structures are disclosed in U.S. Pat. No. 6,929,186 ("Orientation-indicating machine-readable coded data") filed by the applicant or assignee of the present invention and the contents of which is herein incorporated by reference.

2.6 Tag Map

[0116] Decoding a tag typically results in a region ID, a tag ID, and a tag-relative pen transform. Before the tag ID and the tag-relative pen location can be translated into an absolute location within the tagged region, the location of the tag within the region must be known. This is given by a tag map, a function which maps each tag ID in a tagged region to a corresponding location. The tag map class diagram is shown in FIG. **22**, as part of the netpage printer class diagram.

[0117] A tag map reflects the scheme used to tile the surface region with tags, and this can vary according to surface type. When multiple tagged regions share the same tiling scheme and the same tag numbering scheme, they can also share the same tag map.

[0118] The tag map for a region must be retrievable via the region ID. Thus, given a region ID, a tag ID and a pen transform, the tag map can be retrieved, the tag ID can be translated into an absolute tag location within the region, and the tag-relative pen location can be added to the tag location to yield an absolute pen location within the region.

[0119] The tag ID may have a structure which assists translation through the tag map. It may, for example, encode Cartesian (x-y) coordinates or polar coordinates, depending on the surface type on which it appears. The tag ID structure is dictated by and known to the tag map, and tag IDs associated with different tag maps may therefore have different structures.

[0120] With the tagging scheme described above, the tags usually function in cooperation with associated visual elements on the netpage. These function as user interactive elements in that a user can interact with the printed page using an appropriate sensing device in order for tag data to be read by the sensing device and for an appropriate response to be generated in the netpage system.

[0121] Additionally (or alternatively), decoding a tag may be used to provide orientation data indicative of the yaw of the pen relative to the surface. The orientation data may be determined using, for example, the orientation axis **16** described above (Section 2.3) or orientation data embedded in the tag data (Section 2.5).

3 Document and Page Descriptions

[0122] A preferred embodiment of a document and page description class diagram is shown in FIGS. **12** and **13**.

[0123] In the netpage system a document is described at three levels. At the most abstract level the document **836** has a hierarchical structure whose terminal elements **839** are associated with content objects **840** such as text objects, text style objects, image objects, etc. Once the document is printed on a printer with a particular page size, the document is paginated and otherwise formatted. Formatted terminal elements **835** will in some cases be associated with content objects which are different from those associated with their corresponding terminal elements, particularly where the content objects are style-related. Each printed instance of a document and page is also described separately, to allow input captured through a particular page instance **830** to be recorded separately from input captured through other instances of the same page description.

[0124] The presence of the most abstract document description on the page server allows a copy of a document to be printed without being forced to accept the source document's specific format. The user or a printing press may be requesting a copy for a printer with a different page size, for example. Conversely, the presence of the formatted document description on the page server allows the page server to efficiently interpret user actions on a particular printed page.

[0125] A formatted document **834** consists of a set of formatted page descriptions **5**, each of which consists of a set of formatted terminal elements **835**. Each formatted element has a spatial extent or zone **58** on the page. This defines the active area of input elements such as hyperlinks and input fields.

[0126] A document instance **831** corresponds to a formatted document **834**. It consists of a set of page instances **830**, each of which corresponds to a page description **5** of the formatted document. Each page instance **830** describes a single unique printed netpage **1**, and records the page ID **50** of the netpage. A page instance is not part of a document instance if it represents a copy of a page requested in isolation.

[0127] A page instance consists of a set of terminal element instances **832**. An element instance only exists if it records instance-specific information. Thus, a hyperlink instance exists for a hyperlink element because it records a transaction ID **55** which is specific to the page instance, and a field instance exists for a field element because it records input specific to the page instance. An element instance does not exist, however, for static elements such as textflows.

[0128] A terminal element **839** can be a visual element or an input element. A visual element can be a static element **843** or a dynamic element **846**. An input element may be, for example, a hyperlink element **844** or a field element **845**, as shown in FIG. **14**. Other types of input element are of course possible, such a input elements, which select a particular mode of the pen **101**.

[0129] A page instance has a background field **833** which is used to record any digital ink captured on the page which does not apply to a specific input element.

[0130] In the preferred form of the invention, a tag map **811** is associated with each page instance to allow tags on the page to be translated into locations on the page.

4 The Netpage Network

[0131] In one embodiment, a netpage network consists of a distributed set of netpage page servers **10**, netpage registration servers **11**, netpage ID servers **12**, netpage application servers **13**, and netpage relay devices **601** connected via a network **19** such as the Internet, as shown in FIG. **3**.

[0132] The netpage registration server **11** is a server which records relationships between users, pens, printers and applications, and thereby authorizes various network activities. It authenticates users and acts as a signing proxy on behalf of authenticated users in application transactions. It also provides handwriting recognition services. As described above, a netpage page server **10** maintains persistent information about page descriptions and page instances. The netpage network includes any number of page servers, each handling a subset of page instances. Since a page server also maintains user input values for each page instance, clients such as netpage relays **601** send netpage input directly to the appropriate page server. The page server interprets any such input relative to the description of the corresponding page.

[0133] A netpage ID server **12** allocates document IDs **51** on demand, and provides load-balancing of page servers via its ID allocation scheme.

[0134] A netpage relay **601** uses the Internet Distributed Name System (DNS), or similar, to resolve a netpage page ID **50** into the network address of the netpage page server **10** handling the corresponding page instance.

[0135] A netpage application server **13** is a server which hosts interactive netpage applications.

[0136] Netpage servers can be hosted on a variety of network server platforms from manufacturers such as IBM, Hewlett-Packard, and Sun. Multiple netpage servers can run concurrently on a single host, and a single server can be distributed over a number of hosts. Some or all of the functionality provided by netpage servers, and in particular the functionality provided by the ID server and the page server, can also be provided directly in a netpage appliance such as a netpage printer, in a computer workstation, or on a local network.

5 The Netpage Pen

[0137] The active sensing device of the netpage system may take the form of a clicker (for clicking on a specific position on a surface), a pointer having a stylus (for pointing or gesturing on a surface using pointer strokes), or a pen having a marking nib (for marking a surface with ink when pointing, gesturing or writing on the surface). A pen **101** is described herein, although it will be appreciated that clickers and pointers may have similar features. The pen **101** uses its embedded controller **134** to capture and decode netpage tags from a page via an image sensor. The image sensor is a solid-state device provided with an appropriate filter to permit sensing at only near-infrared wavelengths. As described in more detail below, the system is able to sense when the nib is in contact with the surface, and the pen is able to sense tags at a sufficient rate to capture human handwriting (i.e. at 200 dpi or greater and 100 Hz or faster). Information captured by the pen may be encrypted and wirelessly transmitted to the printer (or base station), the printer or base station interpreting the data with respect to the (known) page structure.

[0138] The preferred embodiment of the netpage pen **101** operates both as a normal marking ink pen and as a non-marking stylus (i.e. as a pointer). The marking aspect, however, is not necessary for using the netpage system as a browsing system, such as when it is used as an Internet interface. Each netpage pen is registered with the netpage system and has a unique pen ID **61**. FIG. **11** shows the netpage pen class diagram, reflecting pen-related information maintained by a registration server **11** on the netpage network.

[0139] When the nib is in contact with a netpage, the pen determines its position and orientation relative to the page. The nib is attached to a force sensor, and the force on the nib is interpreted relative to a threshold to indicate whether the pen is "up" or "down". This allows an interactive element on the page to be 'clicked' by pressing with the pen nib, in order to request, say, information from a network. Furthermore, the force may be captured as a continuous value to allow, say, the full dynamics of a signature to be verified.

[0140] The pen determines the position and orientation of its nib on the netpage by imaging, in the infrared spectrum, an area **193** of the page in the vicinity of the nib. It decodes the nearest tag and computes the position of the nib relative to the tag from the observed perspective distortion on the imaged tag and the known geometry of the pen optics. Although the position resolution of the tag may be low, because the tag density on the page is inversely proportional to the tag size, the adjusted position resolution is quite high, exceeding the minimum resolution required for accurate handwriting recognition.

[0141] Pen actions relative to a netpage are captured as a series of strokes. A stroke consists of a sequence of time-stamped pen positions on the page, initiated by a pen-down event and completed by the subsequent pen-up event. A stroke is also tagged with the page ID **50** of the netpage whenever the page ID changes, which, under normal circumstances, is at the commencement of the stroke.

[0142] Each netpage pen has a current selection **826** associated with it, allowing the user to perform copy and paste operations etc. The selection is timestamped to allow the system to discard it after a defined time period. The current selection describes a region of a page instance.

[0143] It consists of the most recent digital ink stroke captured through the pen relative to the background area of the page. It is interpreted in an application-specific manner once it is submitted to an application via a selection hyperlink activation.

[0144] Each pen has a current nib **824**. This is the nib last notified by the pen to the system. In the case of the default netpage pen described above, either the marking black ink nib or the non-marking stylus nib is current. Each pen also has a current nib style **825**. This is the nib style last associated with the pen by an application, e.g. in response to the user selecting a color from a palette. The default nib style is the nib style associated with the current nib. Strokes captured through a pen are tagged with the current nib style. When the strokes are subsequently reproduced, they are reproduced in the nib style with which they are tagged.

[0145] The pen **101** may have one or more buttons **209**. As described in U.S. application Ser. No. 11/672,950 filed on Feb. 8, 2007 (the contents of which is herein incorporated by reference), the button(s) may be used to determine a mode or behavior of the pen, which, in turn, determines how a stroke or, more generally, interaction data is interpreted by the page server **10**.

[0146] Whenever the pen is within range of a relay device **601** with which it can communicate, the pen slowly flashes its "online" LED. When the pen fails to decode a stroke relative to the page, it momentarily activates its "error" LED. When the pen succeeds in decoding a stroke relative to the page, it momentarily activates its "ok" LED.

[0147] A sequence of captured strokes is referred to as digital ink. Digital ink forms the basis for the digital exchange of drawings and handwriting, for online recognition of handwriting, and for online verification of signatures.

[0148] The pen is typically wireless and transmits digital ink to the relay device **601** via a short-range radio link. The transmitted digital ink is encrypted for privacy and security and packetized for efficient transmission, but is always flushed on a pen-up event to ensure timely handling in the printer.

[0149] When the pen is out-of-range of a relay device **601** it buffers digital ink in internal memory, which has a capacity of over ten minutes of continuous handwriting. When the pen is once again within range of a relay device, it transfers any buffered digital ink.

[0150] A pen can be registered with any number of relay devices, but because all state data resides in netpages both on paper and on the network, it is largely immaterial which relay device a pen is communicating with at any particular time.

[0151] One embodiment of the pen is described in greater detail in Section 7 below, with reference to FIGS. **8** to **10**.

6 Netpage Interaction

[0152] The netpage relay device **601** receives data relating to a stroke from the pen **101** when the pen is used to interact with a netpage **1**. The coded data **3** of the tags **4** is read by the pen when it is used to execute a movement, such as a stroke. The data allows the identity of the particular page to be determined and an indication of the positioning of the pen relative to the page to be obtained. Interaction data, typically comprising the page ID **50** and at least one position of the pen, is transmitted to the relay device **601**, where it resolves, via the DNS, the page ID **50** of the stroke into the network address of the netpage page server **10** which maintains the corresponding page instance **830**. It then transmits the stroke to the page server. If the page was recently identified in an earlier stroke, then the relay device may already have the address of the relevant page server in its cache. Each netpage consists of a compact page layout maintained persistently by a netpage page server (see below). The page layout refers to objects such as images, fonts and pieces of text, typically stored elsewhere on the netpage network.

[0153] When the page server receives the stroke from the pen, it retrieves the page description to which the stroke applies, and determines which element of the page description the stroke intersects. It is then able to interpret the stroke in the context of the type of the relevant element.

[0154] A "click" is a stroke where the distance and time between the pen down position and the subsequent pen up position are both less than some small maximum. An object which is activated by a click typically requires a click to be activated, and accordingly, a longer stroke is ignored. The failure of a pen action, such as a "sloppy" click, to register may be indicated by the lack of response from the pen's "ok" LED.

[0155] Hyperlinks and form fields are two kinds of input elements, which may be contained in a netpage page description. Input through a form field can also trigger the activation of an associated hyperlink. These types of input elements are described in further detail in the above-identified patents and patent applications, the contents of which are herein incorporated by cross-reference.

7 Detailed Netpage Pen Description

7.1 Pen Mechanics

[0156] Referring to FIGS. **8** and **9**, the pen, generally designated by reference numeral **101**, includes a housing **102** in the form of a plastics moulding having walls **103** defining an interior space **104** for mounting the pen components. Mode selector buttons **209** are provided on the housing **102**. The pen top **105** is in operation rotatably mounted at one end **106** of the housing **102**. A semi-transparent cover **107** is secured to the opposite end **108** of the housing **102**. The cover **107** is also of moulded plastics, and is formed from semi-transparent material in order to enable the user to view the status of the LED mounted within the housing **102**. The cover **107** includes a main part **109** which substantially surrounds the end **108** of the housing **102** and a projecting portion **110** which projects back from the main part **109** and fits within a corresponding slot **111** formed in the walls **103** of the housing **102**. A radio antenna **112** is mounted behind the projecting portion **110**, within the housing **102**. Screw threads **113** surrounding an aperture **113**A on the cover **107** are arranged to receive a metal end piece **114**, including corresponding screw threads **115**. The metal end piece **114** is removable to enable ink cartridge replacement.

[0157] Also mounted within the cover **107** is a tri-color status LED **116** on a flex PCB **117**. The antenna **112** is also mounted on the flex PCB **117**. The status LED **116** is mounted at the top of the pen **101** for good all-around visibility.

[0158] The pen can operate both as a normal marking ink pen and as a non-marking stylus. An ink pen cartridge **118** with nib **119** and a stylus **120** with stylus nib **121** are mounted side by side within the housing **102**. Either the ink cartridge nib **119** or the stylus nib **121** can be brought forward through open end **122** of the metal end piece **114**, by rotation of the pen top **105**. Respective slider blocks **123** and **124** are mounted to the ink cartridge **118** and stylus **120**, respectively. A rotatable cam barrel **125** is secured to the pen top **105** in operation and arranged to rotate therewith. The cam barrel **125** includes a cam **126** in the form of a slot within the walls **181** of the cam barrel. Cam followers **127** and **128** projecting from slider blocks **123** and **124** fit within the cam slot **126**. On rotation of the cam barrel **125**, the slider blocks **123** or **124** move relative to each other to project either the pen nib **119** or stylus nib **121** out through the hole **122** in the metal end piece **114**. The pen **101** has three states of operation. By turning the top **105** through 90° steps, the three states are:

[0159] Stylus **120** nib **121** out;

[0160] Ink cartridge **118** nib **119** out; and

[0161] Neither ink cartridge **118** nib **119** out nor stylus **120** nib **121** out.

[0162] A second flex PCB **129**, is mounted on an electronics chassis **130** which sits within the housing **102**. The second flex PCB **129** mounts an infrared LED **131** for providing infrared radiation for projection onto the surface. An image sensor **132** is provided mounted on the second flex PCB **129** for receiving reflected radiation from the surface. The second flex PCB **129** also mounts a radio frequency chip **133**, which includes an RF transmitter and RF receiver, and a controller chip **134** for controlling operation of the pen **101**. An optics block **135** (formed from moulded clear plastics) sits within the cover **107** and projects an infrared beam onto the surface and receives images onto the image sensor **132**. Power supply wires **136** connect the components on the second flex PCB **129** to battery contacts **137** which are mounted within the cam barrel **125**. A terminal **138** connects to the battery contacts **137** and the cam barrel **125**. A three volt rechargeable battery **139** sits within the cam barrel **125** in contact with the battery contacts. An induction charging coil **140** is mounted about the second flex PCB **129** to enable recharging of the battery **139** via induction. The second flex PCB **129** also mounts an infrared LED **143** and infrared photodiode **144** for detecting displacement in the cam barrel **125** when either the stylus either the stylus **120** or the ink cartridge **118** is used for writing, in order to enable a determination of the force being applied to the surface by the pen nib **119** or stylus nib **121**. The IR photodiode **144** detects light from the IR LED **143** via reflectors (not shown) mounted on the slider blocks **123** and **124**.

[0163] Rubber grip pads **141** and **142** are provided towards the end **108** of the housing **102** to assist gripping the pen **101**, and top **105** also includes a clip **142** for clipping the pen **101** to a pocket.

7.2 Pen Controller

[0164] The pen **101** is arranged to determine the position of its nib (stylus nib **121** or ink cartridge nib **119**) by imaging, in the infrared spectrum, an area of the surface in the vicinity of the nib. It records the location data from the nearest location tag, and is arranged to calculate the distance of the nib **121** or **119** from the location tab utilising optics **135** and controller chip **134**. The controller chip **134** calculates the orientation (yaw) of the pen using an orientation indicator in the imaged tag, and the nib-to-tag distance from the perspective distortion observed on the imaged tag.

[0165] Utilising the RF chip **133** and antenna **112** the pen **101** can transmit the digital ink data (which is encrypted for security and packaged for efficient transmission) to the computing system.

[0166] When the pen is in range of a relay device **601**, the digital ink data is transmitted as it is formed. When the pen **101** moves out of range, digital ink data is buffered within the pen **101** (the pen **101** circuitry includes a buffer arranged to store digital ink data for approximately 12 minutes of the pen motion on the surface) and can be transmitted later.

[0167] In Applicant's U.S. Pat. No. 6,870,966, the contents of which is incorporated herein by reference, a pen **101** having an interchangeable ink cartridge nib and stylus nib was described.

[0168] Accordingly, and referring to FIG. **27**, when the pen **101** connects to the computing system, the controller **134** notifies the system of the pen ID, nib ID **175**, current absolute time **176**, and the last absolute time it obtained from the system prior to going offline. The pen ID allows the computing system to identify the pen when there is more than one pen being operated with the computing system.

[0169] The nib ID allows the computing system to identify which nib (stylus nib **121** or ink cartridge nib **119**) is presently being used. The computing system can vary its operation depending upon which nib is being used. For example, if the ink cartridge nib **119** is being used the computing system may defer producing feedback output because immediate feedback is provided by the ink markings made on the surface. Where the stylus nib **121** is being used, the computing system may produce immediate feedback output.

[0170] Since a user may change the nib **119**, **121** between one stroke and the next, the pen **101** optionally records a nib ID for a stroke **175**. This becomes the nib ID implicitly associated with later strokes.

[0171] Cartridges having particular nib characteristics may be interchangeable in the pen. The pen controller **134** may interrogate a cartridge to obtain the nib ID **175** of the cartridge. The nib ID **175** may be stored in a ROM or a barcode on the cartridge. The controller **134** notifies the system of the nib ID whenever it changes. The system is thereby able to determine the characteristics of the nib used to produce a stroke **175**, and is thereby subsequently able to reproduce the characteristics of the stroke itself.

[0172] The controller chip **134** is mounted on the second flex PCB **129** in the pen **101**. FIG. **10** is a block diagram illustrating in more detail the architecture of the controller chip **134**.

[0173] FIG. **10** also shows representations of the RF chip **133**, the image sensor **132**, the tri-color status LED **116**, the IR illumination LED **131**, the IR force sensor LED **143**, and the force sensor photodiode **144**.

[0174] The pen controller chip **134** includes a controlling processor **145**. Bus **146** enables the exchange of data between components of the controller chip **134**. Flash memory **147** and a 512 KB DRAM **148** are also included. An analog-to-digital converter **149** is arranged to convert the analog signal from the force sensor photodiode **144** to a digital signal.

[0175] An image sensor interface **152** interfaces with the image sensor **132**. A transceiver controller **153** and base band circuit **154** are also included to interface with the RF chip **133** which includes an RF circuit **155** and RF resonators and inductors **156** connected to the antenna **112**.

[0176] The controlling processor **145** captures and decodes location data from tags from the surface via the image sensor **132**, monitors the force sensor photodiode **144**, controls the LEDs **116**, **131** and **143**, and handles short-range radio communication via the radio transceiver **153**. It is a medium-performance (~40 MHz) general-purpose RISC processor.

[0177] The processor **145**, digital transceiver components (transceiver controller **153** and baseband circuit **154**), image sensor interface **152**, flash memory **147** and 512 KB DRAM **148** are integrated in a single controller ASIC. Analog RF components (RF circuit **155** and RF resonators and inductors **156**) are provided in the separate RF chip.

[0178] The image sensor is a 215×215 pixel CCD (such a sensor is produced by Matsushita Electronic Corporation, and is described in a paper by Itakura, K T Nobusada, N Okusenya, R Nagayoshi, and M Ozaki, "A 1 mm 50k-Pixel IT CCD Image Sensor for Miniature Camera System", IEEE Transactions on Electronic Devices, Volt 47, number 1, January 2000, which is incorporated herein by reference) with an IR filter.

[0179] The controller ASIC **134** enters a quiescent state after a period of inactivity when the pen **101** is not in contact with a surface. It incorporates a dedicated circuit **150** which monitors the force sensor photodiode **144** and wakes up the controller **134** via the power manager **151** on a pen-down event.

[0180] The radio transceiver communicates in the unlicensed 900 MHz band normally used by cordless telephones, or alternatively in the unlicensed 2.4 GHz industrial, scientific and medical (ISM) band, and uses frequency hopping and collision detection to provide interference-free communication.

[0181] In an alternative embodiment, the pen incorporates an Infrared Data Association (IrDA) interface for short-range communication with a base station or netpage printer.

7.3 Alternative Motion Sensor

[0182] In a further embodiment, the pen **101** includes a pair of orthogonal accelerometers mounted in the normal plane of the pen **101** axis. The accelerometers **190** are shown in FIGS. **9** and **10** in ghost outline.

[0183] The provision of the accelerometers enables this embodiment of the pen **101** to sense motion without reference to surface location tags. Each location tag ID can then identify an object of interest rather than a position on the surface. For example, if the object is a user interface input element (e.g. a command button), then the tag ID of each location tag within the area of the input element can directly identify the input element.

[0184] The acceleration measured by the accelerometers in each of the x and y directions is integrated with respect to time to produce an instantaneous velocity and position.

[0185] Since the starting position of the stroke is not known, only relative positions within a stroke are calculated. Although position integration accumulates errors in the sensed acceleration, accelerometers typically have high resolution, and the time duration of a stroke, over which errors accumulate, is short.

7.4 Additional or Supplementary Motion Sensor

[0186] As will be appreciated from the foregoing, if the Netpage tags **4** encode an x-y coordinate grid, then the Netpage pen **101** can identify its own position relative to the surface by reading any small part of the tag pattern. It can then measure its own motion by determining its position via the tags **4** at a sufficiently high rate. The resulting motion data represents the path of the pen relative to the surface as a sequence of discrete positions. If the motion itself is band limited, e.g. because it is produced by the action of a human hand, and the sampling rate exceeds twice the highest frequency present, then the position samples can be interpolated to exactly reconstruct the continuous path of the pen (ignoring noise, quantisation and end effects). If the sampling rate is inadequate then reconstruction is liable to introduce aliasing artifacts into the reconstructed continuous path. Whether this is a problem is application specific.

[0187] Capturing and subsequently reconstructing the exact path of the pen **101** is important when the motion represents handwriting. It is slightly less important when the motion represents a selection gesture (e.g. circumscription, underlining etc), so long as the pen **101** gives the user adequate control. For a given sampling rate the user can trade reduced speed for increased control.

[0188] A number of motion sensing mechanisms may be employed in a Netpage pen **101** in addition to the image sensor **132** and processor **145**, which images and decodes location-indicating Netpage tags **4**. These typically either measure absolute displacement or relative displacement. For example, an optical mouse that measures displacement relative to an external grid (see U.S. Pat. No. 4,390,873 and U.S. Pat. No. 4,521,772) measures absolute displacement, whereas a mechanical mouse that measures displacement via the movement of a wheel or ball in contact with the surface (see U.S. Pat. No. 3,541,541 and U.S. Pat. No. 4,464,652) measures relative displacement because measurement errors accumulate. An optical mouse that measures displacement relative to surface texture (see U.S. Pat. No. 6,631,218, U.S. Pat. No. 6,281,882, U.S. Pat. No. 6,297,513 and U.S. Pat. No. 4,794,384), measures relative displacement for the same reason. Motion sensors based on point interferometry (see U.S. Pat. No. 6,246,482) or acceleration (see U.S. Pat. No. 4,787,051) also measure relative displacement. The contents of all US patents identified in the preceding paragraph relating to motion sensors are herein incorporated by reference.

[0189] Netpage tags can be used as the basis for measuring absolute displacement in a manner similar to an optical mouse that measures displacement relative to an external grid. Since the tags incorporate regularly-spaced target features, the position of these features can be correlated from one tag image to the next to determine displacement. Since the exact spacing of the targets is known, measurement errors do not accumulate. As described above, the pen **101** can take into account the perspective distortion of the tag pattern to compute a precise displacement. In order to correlate the position of targets between successive tag images, the tag images must overlap so that the correlation is unambiguous. As described in U.S. Pat. No. 7,055,739, so long as the displacement between successive tag images is less than half the target spacing the correlation is unambiguous.

[0190] The path of the pen **101** relative to a surface may usefully be decomposed into three separate components: the shape of the path; the orientation of the path relative to the surface; and the position of the path relative to the surface. The shape may be absolute or relative, in line with whether the motion sensing mechanism measures absolute or relative displacement. The precision of a relative path depends both on the magnitude of measurement errors and the number of measurements (i.e. the duration of the path, assuming a fixed sampling rate). The orientation is only known when the motion sensing mechanism measures motion relative to an external reference of known geometry, such as the Netpage tag pattern or a gridded optical mouse pad. The orientation may only be known modulo the rotational symmetry of the external reference. For example, if the external reference has four-fold symmetry then the orientation may only be known modulo 90 degrees. The position is only known when the external reference, such as the Netpage tag pattern, allows the position to be determined. Table 2 lists motion-sensing mechanisms that illustrate these differences.

TABLE 2

Characteristics of motion-sensing mechanisms

Motion-sensing mechanism	Shape	Orientation	position
texture-sensing optical mouse	relative	no	no
grid-sensing optical mouse	absolute	yes	no
tag-sensing Netpage pen	absolute	yes	yes

[0191] An arbitrary motion sensing mechanism can be used in combination with the Netpage pen's fundamental ability to read a Netpage tag pattern. In the absence of a tag pattern (or any other reference), the pen **101** can capture a relative path shape. In the presence of a tag pattern that only identifies regions, the pen **101** can capture an oriented relative path shape within a region (or across multiple regions). In the presence of a tag pattern that also encodes a location grid, the pen **101** can capture an oriented relative path shape, determine the position of the path by sampling its own absolute position once, and can optionally improve the precision of the path shape by sampling its own position more than once (e.g. sparingly but on a regular basis, or just at the end-points of each stroke) and fitting the path shape to the sampled positions to obtain a positioned, oriented, absolute path.

[0192] Assuming a motion sensing mechanism that generates successive displacement deltas Δs_i (i.e. relative position changes), the corresponding position s_i is updated as follows:

$$s_i = s_{i-1} + \Delta s_i \quad \text{(EQ 1)}$$

[0193] If the motion sensing mechanism is a pair of orthogonal accelerometers in the normal plane of the pen axis (see U.S. Pat. No. 7,105,753), then the instantaneous acceleration a_i measured by the accelerometers is integrated with respect to time to produce an instantaneous velocity delta Δv_i, velocity v_i, and displacement delta Δs_i, using the kinematic equations relating acceleration, velocity and displacement:

$$\Delta v_i = a_i \Delta t \quad \text{(EQ 2)}$$

$$v_i = v_{i-1} + \Delta v_i \quad \text{(EQ 3)}$$

$$\Delta s_i = v_{i-1} \Delta t + 1/2 a_i \Delta t^2 \quad \text{(EQ 4)}$$

[0194] The accuracy of the integration increases with decreasing sampling period Δt (and with decreasing acceleration). Non-linear integration may also be used for greater accuracy. It will be appreciated that these calculations may be performed by the processor **145** described above.

[0195] There are several potential advantages to incorporating an additional relative motion sensing mechanism in a Netpage pen **101**. As noted above, the rate at which the pen **101** reads the Netpage tag pattern can be reduced if motion data is available at a higher rate from another source. This can improve power consumption if the other motion sensing mechanism is relatively efficient, such as an optical mouse chip, a point interferometry device, or accelerometers. In addition, motion sensing remains possible in the absence of a Netpage tag pattern. This is useful when the Netpage pen **101** is used, for example, to generate cursor control commands.

[0196] The present invention has been described with reference to a preferred embodiment and number of specific alternative embodiments. However, it will be appreciated by those skilled in the relevant fields that a number of other embodiments, differing from those specifically described, will also fall within the spirit and scope of the present invention. Accordingly, it will be understood that the invention is not intended to be limited to the specific embodiments described in the present specification, including documents incorporated by cross-reference as appropriate. The scope of the invention is only limited by the attached claims.

1. A method of sensing motion of a sensing device relative to a surface, the method including the steps of:

optically imaging a position-coding pattern disposed on or in the surface;

independently sensing relative position changes of the sensing device using a motion sensor;

generating absolute motion data by determining a plurality of absolute positions of the sensing device relative to the surface using the imaged position-coding pattern;

independently generating relative motion data using the relative position changes sensed by the motion sensor; and

determining the motion of the sensing device using the absolute motion data supplemented with the relative motion data.

2. The method of claim **1**, wherein an extent to which the relative motion data supplements the absolute motion data is dependent on at least one of:

a sampling rate of imaging the position-coding pattern;

a speed of movement of the sensing device relative to the surface; and

power-saving criteria for the sensing device.

3. The method of claim **1**, wherein the motion sensor is selected from any one of the group comprising: at least one accelerometer; a mechanical mouse; an optical mouse; and a point interferometry device.

4. The method of claim **3**, wherein said motion sensor is an optical mouse utilizing at least one of: a pattern-based optical mouse technique; a texture-based optical mouse technique; and a laser-speckle-based optical mouse technique.

5. The method of claim **1**, wherein the absolute motion data comprises a plurality of sensed absolute positions, the relative motion data comprises a plurality of sensed relative position changes, and wherein the method includes the further step of:

combining the sensed relative position changes with the sensed absolute positions to generate additional absolute positions.

6. The method of claim **5**, wherein the combining step comprises at least one of:

adding the sensed relative position changes to the sensed absolute positions; and

substracting the sensed relative position changes from the sensed absolute positions.

7. The method of claim **1**, wherein neighbouring absolute positions, as sensed over time, are interleaved with at least one relative position change.

8. The method of claim **1**, wherein the position-coding pattern is indicative of a plurality of locations on the surface and of an identity of a region.

9. The method of claim **8**, further comprising the step of:

determining the identity of the region using the imaged position-coding pattern.

10. The method of claim **8**, wherein the identity of the region is coincident with an identity of the surface.

11. The method of claim **1**, wherein the position-coding pattern is comprised of a plurality of tags, each tag identifying the identity of the surface and a location of the tag on the surface.

12. The method of claim **1**, further comprising the step of:

transmitting data indicative of the motion of the sensing device to a computer system, thereby enabling the computer system to interpret said motion and initiate an action corresponding to said motion.

13. A sensing device configured for determining its own motion relative to a surface, said sensing device comprising:

a first motion sensor comprising:

an image sensor for imaging a position-coding pattern on the surface; and

a first processor configured for generating absolute motion data by determining a plurality of absolute positions of the sensing device relative to the surface using the imaged position-coding pattern;

a second motion sensor configured for independently generating relative motion data by determining one or more relative position changes of the sensing device; and

a second processor configured for determining the motion of the sensing device using the absolute motion data supplemented with the relative motion data.

14. The sensing device of claim **13**, wherein the first and second processors are the same processor.

15. The sensing device of claim **13**, wherein the second processor is configured such that an extent to which the relative motion data supplements the absolute motion data is dependent on at least one of:

a sampling rate of imaging the position-coding pattern;

a speed of movement of the sensing device relative to the surface; and

power-saving criteria for the sensing device.

16. The sensing device of claim **13**, wherein the second motion sensor is selected from any one of the group comprising: at least one accelerometer; a mechanical mouse; an optical mouse; and a point interferometry device.

17. The sensing device of claim **16**, wherein said second motion sensor is an optical mouse utilizing at least one of: a pattern-based optical mouse technique; a texture-based optical mouse technique; and a laser-speckle-based optical mouse technique.

18. The sensing device of **17**, wherein said second motion sensor is an optical mouse comprising the image sensor.

19. The sensing device of claim **13**, further comprising communication means for transmitting data indicative of the motion of the sensing device to a computer system, thereby enabling the computer system to interpret said motion and initiate an action corresponding to said motion.

20. A system for initiating an action corresponding to motion of a sensing device relative to a surface, said system comprising:

(A) the sensing device comprising:

a first motion sensor comprising:

an image sensor for imaging a position-coding pattern on the surface; and

a first processor configured for generating absolute motion data by determining a plurality of absolute positions of the sensing device relative to the surface using the imaged position-coding pattern;

a second motion sensor configured for generating relative motion data by determining one or more relative position changes of the sensing device, said second motion sensor being operatively independent of said first motion sensor;

a second processor configured for determining the motion of the sensing device using the absolute motion data supplemented with the relative motion data; and

communication means for communicating data indicative of the motion of the sensing device to a computer system; and

(B) the computer system configured for:

receiving the data indicative of the motion of the sensing device;

interpreting said motion; and

initiating an action corresponding to the motion of the sensing device.

* * * * *