analysis by 3-D affine deformations

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Earthquake analysis by 3-D affine deformations

Changes in coordinates at stations affected by earthquakes have been monitored successfully, for years, with precision using satellite navigation. Results of interest have then been produced in the past through processing the outcome by conventional means. Those methods can now be augmented by applying entirely different criteria: deformation states associated with affine transformations.

Introduction

An illustration of the methodology used here is available from selected station location histories before and after the Tohoku quake in 2011. Figure 1 shows the chosen stations on a map [1] and Figure 2 depicts them following rotations and normalizations to be described herein. The eleven stations are represented as a 3-D structure consisting of point masses all tethered to their collective centroid by weightless connecting arms that are not quite rigid. With migration the centroid shifts accordingly while the connecting arms rotate and deform to accommodate as necessary. Migration irregularities preclude exact mathematical characterization for the pattern of accommodating adjustments, but a daily affine transformation sequence serves as a useful model for analysis and interpretation - with prospects for anticipating earthquakes in the future.

Background from related fields

Methods from branches of multiple disciplines are highly relevant. For this
first 3-D affine deformation analysis applied to earthquakes, presentation calls for recognition of pertinent sources. At the same time, their descriptions here cannot exceed length restrictions. A full mathematical development, accompanied by the complete set of results to be shown, would violate length limitations. Alternatively that results to be shown, would violate permissible. Wherever possible, verbal descriptions are worded so that the reference will not be needed by those familiar with material being discussed.

Mathematics

Developments of standard tools itemized in this subsection, including derivations, are available from many sources. Major operations include 1) minimum variance estimation, 2) coordinate rotations, 3) diagonalization of 3×3 square matrices, 4) singular value decomposition (svd) of rectangular matrices, and 5) 4×4 affine transformations.

Coverage of the first three items, with some subtle features needed for this specific application included, can be found in [2]. With usage of the block (rather than sequential) estimation, the brief development on pages 159-162 suffices. Even that is more general than needed for the steps followed here (though not for recommended future extensions). Pages 36-38 of [2] cover 3-D coordinate rotations, but that latter page shows a popular small-angle representation acceptable in most operations – though not used here. When rotating vectors of enormous size (hundreds of km), adequate precision must be ensured. Here that translates into approximating the cosine of a small angle – not by unity but by a two-term representation. A direction cosine matrix that rotates through a small angle θ about any axis with unit column vector E, contains three ingredients:

- a 3×3 identity matrix multiplied by (I -½θP)
- θ multiplied by a skew-symmetric matrix corresponding to vector cross product operator (E ×)
- ½θP × (outer product E postmultiplied by its transpose) Those unfamiliar can examine Eq. (2-48) of [2], not limited to small angles.

Another transformation involves reexpression of latitude/longitude/altitude into earth-centered, earth-fixed (ECEF) coordinates. Again the operation is standard; those unfamiliar can examine Eq. (7-31), with (3-18, -19, -22), of [2]. Also the inverse is described in addendum 5.E of [3]. Diagonalization of a square matrix is defined in [2] by Eqs. (II-20, -21, -22), with examples given in pages following them. Standard algorithms are common, e.g.,

\[ [\text{evec}, \text{eval}] = \text{eig(matrix)} \]

in MATLAB. For matrices that are rectangular rather than square a related operation (svd) is used: adequate for purposes here, again from MATLAB,

\[ [\text{M}_u, \text{D}, \text{M}_v] = \text{svd}(\text{U V}^T) \]

The role of the eigenvector matrix denoted “evec” plus the factors denoted \( \text{M}_u, \text{M}_v, \text{U} \), and the transpose \( \text{V}^T \) of \( \text{V} \), are defined in subsections that follow.

Affine transformations, central to this investigation, offer a much wider scope of effects including translation, scaling, and deformation as well as rotation. The standard 4×4 affine transformation in 3-D, being homogeneous, has one less independent state than the number (sixteen) of matrix elements. The fifteen independent states can be categorized in five sets of three, each set having x-, y-, and z-components for translation, rotation, perspective, scaling, and shear. Immediately the three degrees-of-freedom associated with perspective are irrelevant for purposes here. In addition both translation and rotation, clearly having no effect on shape, can be analyzed separately – and the same is likewise true of uniform scaling. It is thus widely known that there are five “shape states” involved in 3-D affine deformations, three for shear and two for nonuniform scaling.

One way to describe shape states is to note their effects in 2-D, where there is only one for nonuniform scaling (which deforms a square into a rectangle) and one for shear (which deforms a rectangle into a parallelogram). Therefore it is suggested here that added insight into earthquake investigation can be obtained by analyzing affine features – with specific attention given to their individual traits (degrees-of-freedom).

For those unfamiliar with affine matrices, [4] provides an excellent thorough introduction plus numerous examples. Due to their central role, they will appear repeatedly in multiple discussions to follow.

Anatomy

Familiarization with the topic now to be broached sometimes begins with the example of facial features (e.g., tip of chin, corners of the eyes and mouth). Those qualified, however, identify landmarks on other anatomical structures for further study (e.g., as a possible diagnostic tool if certain deformations correlate with some affliction). When measurements (e.g., from x-ray images) are processed as described shortly, specific landmarks – even from a wide variety of patients (any nationality, any race, all ages, both sexes) – are found to cluster with some degree of consistency. That trait is physiological, not an artifact of the processing. Also, when the landmarks are remapped after extraction of affine deformations, the clusters shrink; theoretically if only affine deformations were present, clusters would converge to discrete points.

The universally recognized reference [5] contains thorough descriptions of the entire process plus a wealth of results, along with a full derivation (from pages 138-142) developed by the author of [6] for affine deformation states – all in 2-D. Needless to say this presentation will
not include that derivation, let alone its 3-D extension. What can be realistically offered here will nevertheless enable partial application of this methodology to other data sets, with or without this author’s involvement. Not all of the results to follow require the complete deformation analysis. In generating those results, some very revealing features arose in earlier portions of the overall procedure – without requiring full pursuit to final determination of 3-D deformations. For this data set, at least, understanding can thus be brought to a significant level with just the Procrustes representation, described succinctly as follows:

The previously defined structure of K point masses and nonrigid connecting arms (K = 11 in this study) is first transformed into principal axes of inertia (next subsection) and the origin is translated to the centroid. Division by the root sum square of all coordinates then produces an array containing 3K dimensionless positive and negative numbers whose sum of squares is unity.

With normalization of all magnitudes an orthogonal matrix, computed for each separate day of the sequence, minimizes that day’s sum of squares of rotated landmark changes from the first (“Day #1”). It is formed, as on page 98 of [6] but with notation modified here, as a product $\mathbf{M}_2 \mathbf{M}_1^T$ of outer factors from svd with $\mathbf{U}$ and $\mathbf{V}$, $3 \times K$ matrices produced by the set of Procrustes operations just defined, acting on the data from Day #1 and each subsequent day, respectively.

After forming all Procrustes coordinate matrices and storing columns of $\mathbf{U}$ into vector $\mathbf{U}$, affine transformation provides an array $\mathbf{u}$ of small adjustments for each day’s fitted array $\mathbf{V}$, nominally characterized as $\mathbf{U} + \mathbf{u}$. Explanation is now in order, due to differences from applications to anatomy. Here there is no need to form an average mesh; Day #1’s coordinate set serves as the comparison reference throughout. Also the coordinate adjustments, shape states, and rotations from svd here are are not merely small; they are minuscule – of order 1.e-8. Still the need for precision calls for rigorous computations; over a span of 1000 km, 0.01 radian rotations generate cm displacements. Even with $\mathbf{u}$ orthogonal to $\mathbf{U}$ an adjustment is made; $\mathbf{u}$ is summed – not with $\mathbf{U}$ but with $\mathbf{U}/[\mathbf{U} + \mathbf{u}]$ – see next subsection.

Also of potential interest from the field of anatomy are further deformations represented by a thin plate spline (TPS, which minimizes approximate squared curvature integrated over a surface defined by a landmark set). Nonlinear (unlike affine) deformations are applicable over only local regions rather than entire structures. Full implications of that issue, quite broad in physiological studies, involve complex topics not needed for this landmark analysis (e.g., sophisticated mathematics of Riemannian manifolds and the impact on detailed algorithms for dense correspondence in positioning pixels between landmarks of high resolution images). For this application only the TPS is considered – and only briefly, at that – since results obtained show that variations in the day-to-day bending energy obtained from it are negligible for practical purposes.

Mechanics

Only a few concepts from this branch were used here. It was foreshadowed earlier that adding a miniscule vector orthogonal to a unit vector must not result in a significant length increase. That “arc length constraint” is modified somewhat here; more generally, although the affine deformation vector $\mathbf{u}$ can include expansion/contraction effects, no artificial elongation is introduced through vector addition (hence division of $\mathbf{U}$ by $[\mathbf{U} + \mathbf{u}]$).

Although that same principle theoretically applies to the TPS (which equates curvature to a second derivative without the slight shortening just described), that adjustment has not been found necessary (nor feasible) for TPS fitting.

One of the earliest steps taken prior to determination of deformations is formation of the inertia matrix for the reference configuration (in this case, the set of K point mass landmarks in 3-D on Day #1). With those ECEF coordinates in a $3 \times K$ array $\mathbf{U}$ and its $K \times 3$ transpose $\mathbf{U}^T$ along with its $3K \times 1$ vector $\mathbf{u}$, the inertia matrix contains two terms, • the product $\mathbf{UU}^T$ multiplied by the $3 \times 3$ identity matrix • the product $\mathbf{UU}^T$ multiplied by -1.

Their sum is the matrix to be diagonalized, described earlier.

Strength of Materials

Deformations have spatial derivatives in along-axis and across-axis directions. The latter, in order, are associated with slopes, components of curvature (proportional to bending moments), and curvature gradients (proportional to shearing stress) while along-axis deformations (extension and contraction) are related to tensile and compressive stress. In-depth pursuit of these and other additional forces (e.g., friction) would clearly involve still another field of endeavor, i.e., geology, to take into account tectonic plate characteristics (composition, inhomogeneity, irregular cross-section geometry, elasticity, etc.). Although beyond scope here, a limited effort toward that direction was originally intended, by using an available TPS program. The program did quantify bending energy but, at least for the period of primary interest (pre-quake), those temporary elastic deformations lowered that priority for the data studied. Reasons are traceable to the diminutive

Figure 3: Changes from comparison reference (“Day #1”), in principal axes and relative scaling, pre-quake
changes in coordinates compared to
the distances spanned. Dominance of
other factors would not justify further
emphasis on nonlinear deformations.

**Procedure**

A synopsis of steps summarizes
the preceding descriptions:
• select an ensemble of station
histories to be analyzed
• acquire data in most reliable
and accurate form
• assemble coordinate data into
arrays to prepare operations
• use each separate day’s landmark
set centroid as origin
• form the inertia matrix of the
first day’s landmark set
• diagonalize the inertia matrix
for principal axis resolution
• form a direction cosine matrix
from the eigenvectors
• shrink each day’s centered landmark
coordinate sum of squares to
unity (this step could either
precede or follow the next)
• transform each day’s landmark data set
through the $3 \times 3$ orthogonal matrix
• rotate again per svd from
each day’s data vs Day #1
• compute estimates for each
day’s five shape states
• apply shape states to the
reference (Day #1) data
• backtrack steps to reconstruct input
data; evaluate the fit based on residuals
• prepare all results for
dissemination/presentation

Completion of all steps can enable
interpretation and evaluation of outcome
as means for quake prediction. Toward
that objective, recommendations for
further tasks to be pursued follow
the results now to be presented.

**Quantitative results**

Disturbances appearing in advance
are seen from plots using an abscissa
indexed with the quake at zero. From
data files starting 29 days prior,
then, “Day #1” is indexed at -29.

Each $x$, $y$, and $z$ landmark migration in
Figure 3 appears as a single dot, except
for those depicted by two solid lines used
to show some deviations from general
patterns. Occurring five days and sixteen
days before the quake, they are somewhat
more pronounced in the lower right plot.
Further changes after the quake are
of course larger, but higher priority is
attached here to pre-quake behavior.

While early disturbances are entirely
consistent with past experience,
processing the data in another way can
lend further insight. Here the changes
are reexpressed in terms of the deformed
Procrustes representation used for this
study. To begin that portrayal, pre- plus
post-quake centroid shifts and pre-
quake small rotational adjustments are
shown in Figure 4 and 5, respectively.

The permanence of change in Figure 4 is
obvious and not at all surprising. Again
the foreshadowing at 5 and 16 days pre-
quake are detectable, and of course would
be more clearly visible on a half-duration
plot (i.e., terminating one day before the
quake, as Figure 5 does for the rotational
history). The last two plots offer some
added premonitions. The temporary
character of these advance disturbances
(tendency to return toward earlier forms)
is suggestive of elastic deformations, but
• only a partial restoration occurs, and
• there is some growth of
deformation peaks.

Issues just noted are revisited in later
sections. First it is of interest to follow
through with additional behavior
patterns, starting with a serendipitous
clue that arose while validating the
small-angle rotations of Figure 5.

Formation of the orthogonal matrix
with the outer factors from the svd, as
previously described, was first shown to
provide the minimization as promised.
That verification produced Figure 6,
now described as follows: Separately
in sequence, centroids of each day’s $K$
landmark appendages collocate with that of
Day #1. Migration nonuniformity precludes
coincidence of point mass extremities but
the sum of squared separation distances
is minimized by the orthogonal matrix
from the svd. Multiplying the angle
through a span of values (from too little
to too much rotation) always made the
closest combination for a multiplier
of unity. Generally the sum of squares
tends to grow as the quake draws near
(except for the same days already noted
and also one day ahead. No definitive
diagnosis will be attempted from this
amount of data, except to say that the
phenomenon warrants wider investigation.

As one step toward wider scrutiny,
sensitivity to the rotation axis direction
was also determined. Resulting 3-D

![Figure 4: Centroid movement, before and after quake](image1)

![Figure 5: Rotation for Procrustes fit, pre-quake](image2)
AMAZING SKILLS OF THE WORLD

INSPIRE US ...

When size, performance and robustness matter
images for 29 days cannot be plotted together without masking each other, but the outcome is similar. The three days noted in Fig. 6 exhibited abnormal sensitivity to the direction, as well as the amount, of rotation. Furthermore, also on those same days, at least three shape states (not always the exact same set) temporarily jumped beyond their normally moderate growth trend.

Before switching attention to the shape states, it is noted that behavior of this data set is not guaranteed to hold in general. Other attributes could arise from chosen landmark sets with dissimilar layout geometries (or even from an alternative choice of shape states for this data set – recall that there are two expansion / contraction states covering three directions). These points facilitate understanding Figure 7 but, again, no generalization will be attempted here; data from other quakes could show different behavior.

Figure 7 is seen to be consistent with discussion preceding it, while exhibiting numerical values comparable to the rotation states of Figure 5. Also, local pre-quake peaks are again apparent in the expansion / contraction state line plots and the symbols representing shear states. Immediately a question can arise, regarding conformance of this model to migrations actually observed. Numerous plots vs time and vs landmark number, made to evaluate that conformance, are discussed next.

Coordinate plots computed from the model, together with actual observations, seem impressive but not informative (points “coincide” when migrations are dwarfed by distances between landmarks). Alternatively a migrations-only plot, showing departures of modeled from observed values, exhibit the limitations more clearly - but without indicating what constitutes “good” performance. Figure 8 exemplifies the information desired by showing migrations actually observed together with errors in modeling them.

The total volume of data (in three directions from eleven landmarks over a period of weeks) necessitated a way to compact the results for this affine model. That effort, applied to RSS values (3-D \(x, y, z\)), produced Figure 9 described as follows: Most residuals (shown with a dot •) fall very near or below the dashed horizontal line at 2 cm. Exceptions are

- values obtained at 16 and 5 days pre-quake (the main “early warning” days, light dashed vertical lines)
- landmark #5 (closest to the epicenter), whose residuals are enclosed within a square
- two others (shown encircled) at about 2.2 and 2.6 cm.

To reiterate, all residuals are below 4 cm., almost 98% are below 3, and over 91% are below 2. All but two of the values significantly above 2 cm are either from the station nearest epicenter or from one of the key early warning days.

With 3-D RSS migration reaching a maximum of almost 15 cm amidst dispersions of a few cm, these results are consistent with performance expected from minimum variance estimation. By analogy with a straight line or low order curve fitted to scattered empirical data, a least squares fit here captures the larger migrations while accepting residuals commensurate with the dispersion in the data.

Some further discussion of these residuals is warranted. The plot of this full set in Figure 9 was preceded by a partial glimpse (Figure 8), in one of three principal (not ECEF) axes from one of eleven landmarks. Few partial plots look as good as that sample. For landmarks with smaller migrations (4 or 5 cm maximum), a nominal 2-cm dispersion is less impressive – and individual excursion components from some landmarks were in fact less than 2 cm. What those cases contribute, to be blunt, “just looks like a bunch of dots thrown all over the place.”

A fitted model will not adhere to the points. Attempts to force model fidelity are readily dismissed; many will recall MATLAB’s “doomsday” polynomial fitted to empirical global population history.

Model credence for data analyzed here rests on acceptance of 2-cm residuals as a reasonable (though admittedly not trivial) price to pay for a means of characterization. Immediately a caveat might be raised: Shouldn’t that be changed – contingent on acceptance of 4-cm residuals? Actually no; aside from the two circled points in figure 9 (beyond 2 cm by modest amounts), the “problem” of larger residuals is in reality the opposite of a problem.

They offer valuable revelations, in time (premonitions at 16 and 5 days pre-quake) and spatially – most of them correspond
to the landmark closest to epicenter! As with other facets of this investigation, no generalization will be attempted – but other quakes should be examined for these traits.

Data for verification

As promised, data will now be included to enable duplication of certain results – and subsequent application to observations from other quakes. A full data set, even from the limited scope of this study, would be unwieldy – but coordinates at Day #I and at five days prequake allow revealing traits to be exhibited. Those values, in centimeters, are obtained through multiplication by \(1.e+8\) the next two tabulations for \(x\), \(y\), and \(z\):

**Day #I**

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<th>(y)</th>
<th>(z)</th>
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**5 Days Pre-Quake**

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</table>

The following results are verifiable from Day #I data:

The inertia matrix is \(1.e+17\) *

\[
\begin{bmatrix}
2.4754 & -0.1670 & -0.5725 \\
-0.1670 & 2.1793 & 0.7581 \\
-0.5725 & 0.7581 & 1.6339
\end{bmatrix}
\]

with eigenvalues \(1.e+17\) *

\[
[2.1885 \quad 3.1018 \quad 0.9983]
\]

and eigenvectors producing the matrix “evec”

\[
\begin{bmatrix}
0.7239 & -0.6369 & -0.2651 \\
0.6693 & 0.5550 & 0.4940 \\
0.1675 & 0.5351 & -0.8280
\end{bmatrix}
\]

Certain missions demand unsurpassed precision, stability and reliability. Having perfect control and fully understanding the smallest detail is what it takes to be a world leader.

With this in mind, we developed the Inertial Measurement Unit STIM300, a small, ultra-high performance, non-GPS aided IMU:

- ITAR free
- Small size, low weight and low cost
- Insensitive to magnetic fields
- Low gyro bias instability (0.5°/h)
- Low gyro noise (0.15°/√h)
- Excellent accelerometer bias instability (0.05mg)
- 3 inclinometers for accurate leveling

STIM300 is the smallest and highest performing, commercially available IMU in its category, worldwide!

A miniature IMU
Weight: 0.12 lbs (55g)
Volume: 2.0 cu. in. (35cm³)

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From both days’ centroid-referenced coordinates the svd produces a small-angle rotation vector equal to \(1.e-7 \times \begin{bmatrix} .14830897738546 & -.04830307526257 & -.20219407067329 \end{bmatrix}\) which together with principal-axis rotation via “evec” enables validation of the top curve on the left of Figure 6.

Additional data will now be presented to enable an accuracy evaluation for the affine fit to the preceding tabulation of pre-quake coordinates. The deformation vector obtained for that day was the product \(1.e-9\) multiplied by \([-0.456365 -5.20928 4.77305 3.19895 -13.2300]\). The accompanying plot shows, in cm, RSS migrations and backtrace-reconstructed coordinate residuals in ECEF. Figure 9’s largest residuals, “BTW” encouragingly, occur at a landmark other than that with largest migrations. Also, RSS migrations and reconstructed coordinate residuals in principal axes rather than in ECEF produced subplots somewhat (but not dramatically) better than Figure 10. From material already presented it could be anticipated that

- individual \((x, y, \text{and } z)\) components exhibit some traits that are more impressive (small residuals with relatively large migrations) and some that are less so (migrations and residuals both near 2 cm).
- the former are reminiscent of Figure 8 while the latter call to mind the “bunch of dots” perception.

Many other plots were generated whose presence here might add only marginally to material already shown. Post-quake time histories, for example, show poorer adherence to affine modeling – even with the “Day #1” reference moved to the first day after the quake. Additional prospects, seeming to warrant further attention even pre-quake, were noticed but not yet fully pursued. Of primary importance at this stage of presentation is a clear understanding of what the affine fit – based on evidence obtained thus far – offers toward quake anticipation. In brief, the least squares fit appears to

- provide awareness of the larger landmark excursions while “middling and muddling through” the smaller and, in the process of doing that,
- suggest clues in advance regarding time and location

Limits of time and space now prompt a shift of attention to listing of areas deserving extended investigation.

The accompanying plot shows, in cm, RSS migrations and backtrace-reconstructed coordinate residuals in ECEF.

Figure 8’s example of desired performance \((y\text{-coordinate of Landmark 4): Low residuals (“•”) with larger migrations (“o”)}\)

| \(u\) coordinate increments formed through premultiplying the \(5\times1\) deformation vector by this matrix: |
|---|---|---|---|---|
| 0.2075 | 0.1566 | 0.0510 | 0.1961 | -0.0152 |
| 0.0273 | 0.0381 | 0.0107 | -0.0218 | 0.2820 |
| 0.1942 | 0.2346 | 0.4288 | -0.0505 | -0.0089 |
| -0.1007 | -0.0002 | -0.1005 | 0.3453 | -0.0267 |
| 0.0481 | 0.0269 | -0.0212 | 0.0000 | -0.0003 |
| 0.3420 | -0.0003 | 0.3417 | 0.0996 | 0.0176 |
| -0.1939 | -0.0225 | -0.1714 | 0.1607 | -0.0124 |
| 0.0224 | -0.0137 | -0.0361 | 0.0031 | -0.0405 |
| 0.1591 | -0.0337 | 0.1254 | 0.1697 | 0.0301 |
| 0.0113 | -0.2693 | 0.2805 | 0.3954 | -0.0306 |
| 0.0551 | 0.1142 | 0.0591 | 0.0375 | -0.4851 |
| 0.3916 | -0.4035 | -0.0119 | -0.2778 | -0.0492 |
| 0.1639 | 0.1852 | -0.0213 | -0.0300 | 0.0023 |
| -0.0042 | -0.0087 | -0.0045 | -0.0258 | 0.3336 |
| -0.0297 | 0.2775 | 0.2477 | 0.0211 | 0.0037 |
| -0.5881 | -0.3105 | -0.2776 | -0.2267 | 0.0175 |
| -0.0316 | -0.0901 | -0.0585 | 0.0433 | -0.5594 |
| -0.2245 | -0.4653 | -0.6898 | 0.2749 | 0.0487 |
| 0.1682 | 0.1868 | -0.0186 | 0.0257 | -0.0020 |
| 0.0036 | -0.0003 | -0.0039 | -0.0260 | 0.3365 |
| 0.0255 | 0.2799 | 0.3054 | 0.0184 | 0.0033 |
| -0.1513 | 0.0150 | -0.1663 | 0.0002 | -0.0000 |
| 0.0000 | -0.0350 | -0.0351 | -0.0021 | 0.0269 |
| 0.0002 | 0.0224 | 0.0226 | 0.1646 | 0.0292 |
| 0.0869 | 0.0020 | 0.0849 | -0.4517 | 0.0349 |
| -0.0629 | -0.0450 | 0.0179 | -0.0003 | 0.0035 |
| -0.4472 | 0.0029 | -0.4443 | -0.0841 | -0.0149 |
| 0.2573 | 0.1682 | 0.0892 | -0.1269 | 0.0098 |
| -0.0177 | 0.0011 | 0.0188 | -0.0234 | 0.3029 |
| -0.1257 | 0.2520 | 0.1263 | -0.0883 | -0.156 |
| 0.1389 | -0.1111 | 0.2500 | -0.2882 | 0.0223 |
| -0.0402 | 0.0126 | 0.0527 | 0.0155 | -0.2002 |
| -0.2854 | -0.1665 | -0.4519 | -0.2476 | -0.0438 |

Figure 9: Complete set of RSS residuals \(\text{(near-epicenter values enclosed within a square), approx. 2 cm dispersion range}\)
Other possible extensions, probably with lower priority at present, might include pursuing the TPS further, addition of deformations with spatial nonlinearities (i.e., nonlinear only w.r.t. position but not nonlinear w.r.t. the state – in analogy with linear estimation for a quadratic or cubic polynomial fit), or other non-affine deformation patterns (e.g., twist). In any case, highest value will be attached to models showing consistency with empirical quake data, and experience gained from analyzing past histories will offer predictive capabilities for the future.

Further promising applications (with suitable modification): tsunami prediction [8] and aging infrastructure.

Acknowledgment

Prof. Frank van Graas and Ryan Kollar of Ohio University provided all landmark data for this investigation. Without their diligent acquisition and validation of the data, none of the results presented here could have been generated. They join me in appreciation of the opportunity to pool our efforts with others in this field, toward reducing the danger to those at risk from earthquakes.

Conclusions

For investigation of earthquakes based on their affine degrees-of-freedom, methodology of another field – anatomy – is highly relevant. Instead of designated landmark sets coming from a group of patients, here they are associated with a series of days (e.g., from several days before to several days after a quake). Each landmark set is then subjected to a sequence of procedures thoroughly familiar to anatomy experts and succinctly reviewed herein.

Physiological studies of affine deformations in current practice ironically lack a crucial feature; they concentrate heavily on two-dimensional representations. While full affine representation is very old, its inversion (i.e., optimal estimation of shape states from a given overdetermined coordinate set) has heretofore been limited to 2-D. Immediately then, extension was required for adaptation. The fundamentals still remain applicable, however, as indicated by several plots presented in this paper.

A serendipitous discovery, verifiable from data included here and easily applied to other quake histories, calls for further investigation. Sensitivity to incremental rotations, formulated from Procrustes representation even without computing affine deformations, jumped beyond range before returning to "normal" – twice, well in advance of the quake (i.e., first by sixteen days and subsequently by five days). That behavior, plus other results shown herein, exhibit encouraging prospects for warnings in advance of quakes (and potentially, tsunamis or infrastructure failures).

References


Figure 10: Migrations (‘x’) and residuals (‘•’), Day ’−5’
“Business momentum has been rising each month during 2013”

Says Francois Erceau, General Manager, GeoInstruments, Spectra Precision Division

Ashtech invests heavily in the development of cutting-edge technology. Please elaborate.

The Ashtech name has always been synonymous with original, innovative technologies and ground-breaking solutions, and we continue that tradition within the Spectra Precision business. The focus of our innovation is evolving, as we aim to deliver products that are simpler, easier to use and easier to deploy across a wider range of users.

Support functions. During 2012 we streamlined our product portfolios and expanded the range of products available to our combined sales channels. We also rationalized our back-office systems to take advantage of our parent corporation’s powerful business infrastructure.

To reflect the maturity of our integration, we have recently renamed the combined Spectra Precision/Nikon/Ashtech business as the “GeoInstruments” business area within Spectra Precision.

How significant is the accessories market share for Spectra Precision?

We offer an extensive range of accessories tailored for our Spectra Precision and Nikon branded surveying and construction products. Additionally, we have within Spectra Precision a vast array of more generalized accessories under both the Spectra Precision and SECO brands. Overall, our accessory portfolio is the broadest in the industry: bar none!

How does the OEM business of Ashtech contribute to the overall business of Spectra Precision?

The Ashtech-branded GNSS boards and Integrator-ready GNSS receivers are now managed as part of the Trimble Integrated Technologies (OEM) business. That business sells not only GNSS technology but also digital radio technology and other integrator offerings including software and services. The Ashtech GNSS OEM portfolio nicely complements the existing Trimble “BD” range of GNSS boards, providing integrators with a wide range of options and capabilities to choose from.

How has been the journey so far after formation of Spectra Precision’s GeoInstruments business?

During 2011, our main focus was on merging the Spectra Precision/Nikon and Ashtech teams, with emphasis on R&D, Sales, Marketing and Operational

How has been the journey so far after formation of Spectra Precision’s GeoInstruments business?

During 2012 we streamlined our product portfolios, replacing older products and closing the few gaps that remain. With our combined organization we can leverage greater R&D resources and the steady stream of product announcements already this year demonstrate our commitment to meeting our customers’ needs. In January we launched the NPL-322 entry-level reflectorless total station family, and in March we introduced the world’s lightest GNSS RTK receiver, the ProMark 700. We continue to refine our Survey Pro field software, with a new version shipping in April. And our new Layout Pro solution for construction has recently been updated with support for the FOCUS 30 robotic total station.

As they say in show business, “there’s plenty more to come”.

How your products like ProMark and Epoch address the users’ needs in GNSS surveying?

Our ProMark and EPOCH GNSS systems are designed by surveyors, for surveyors. We integrate all the features you’re going to need in the field (including cellular and UHF communications), and we leave out anything that’s just going to get in your way. Simply Powerful is our promise and these sophisticated but easy-to-use GNSS systems are precisely that.

What are the new product and solution scheduled for release this year for different market segments?

We are continuing to streamline our product portfolios, replacing older products and closing the few gaps that remain. With our combined organization we can leverage greater R&D resources and the steady stream of product announcements already this year demonstrate our commitment to meeting our customers’ needs. In January we launched the NPL-322 entry-level reflectorless total station family, and in March we introduced the world’s lightest GNSS RTK receiver, the ProMark 700. We continue to refine our Survey Pro field software, with a new version shipping in April. And our new Layout Pro solution for construction has recently been updated with support for the FOCUS 30 robotic total station.

As they say in show business, “there’s plenty more to come”.

Tell us about the key features that help FOCUS® 30 Total Station to meet the users’ requirements.

FOCUS 30 is an amazing instrument: it boasts innovative tracking capabilities, high speed and superlative accuracy. Coupled with the Ranger 3 data collector it ensures productive surveying all day, every day.

In addition to our Survey Pro software for intensive professional surveying...
applications, we now offer the FOCUS 30 robotic instrument with Layout Pro software, for construction layout applications. The introduction of mechanical total stations revolutionized the way layout is done, but there’s a quantum leap in productivity when you use a robotic instrument to do layout. The digital CAD design literally leaps off the page and onto the ground, enabling rapid, accurate construction immediately after the design has been signed off.

How do you look at the marine and avionics applications?

Within the GeoInstruments business, our sophisticated ProFlex 800 GNSS receiver is frequently used by marine integrators.

In the avionics arena the main product offerings are the Ashtech-branded boards and systems promoted by the Integrated Technologies business of Trimble. The avionics industry has extremely specialized requirements, for example FAA certification, and meeting those requirements requires specialized attention and business focus.

What is Spectra Precision’s preparation to the challenges of multi-GNSS scenario?

As you know, we have been at the vanguard of GNSS-centric technology from the beginning, and indeed we are the only mainstream GNSS vendor offering GNSS-centric technology today. Our Z-Blade GNSS engine allows all available GNSS signals to be used interchangeably, eliminating reliance on any specific GNSS system. So, for example, our Z-Blade GNSS receivers are capable of operating in GLONASS-only or Beidou-only mode if required.

The next few years will bring a plethora of new GNSS signals, and the days of inadequate coverage would seem to be gone, at least for those GNSS receivers that can make use of the new signals without being hampered by old restrictions (such as a reliance on at least 4/5 GPS satellites for example).

Which market segments are your main targets for GNSS receivers?

Within the GeoInstruments business, our main GNSS target markets are land surveying and mobile mapping (GIS). For the most part these markets are addressed with out-of-the-box solutions, but in some regions we work with 3rd party software companies to deliver localized solutions. And we continue to work with a range of special applications such as waste management and on-machine control.

Our mobile mapping products are used in a wide range of applications, from natural resource management to urban asset management and utilities.

What are the marketing challenges faced by you at Spectra Precision?

Our products are sold under the Spectra Precision (all portfolios) and Nikon (optical portfolios only) brands. We continue to acknowledge our history through selective use of the TDS (Tripod Data Systems) brand for surveying software in the US market, and the “Powered by Ashtech” moniker which indicates GNSS products with embedded Ashtech technologies.

Do you think Ashtech is better positioned now after its acquisition by Trimble?

Ashtech customers now have a far wider range of products to choose from, spanning not just GNSS technologies but also optical instruments, lasers, radio and cellular communications technology, software and services. So clearly we are better positioned to serve the needs of those customers, both now and in the future.

For our staff, of course, there is also a much wider range of opportunities as we are now a part of a much larger organization, with many career options and the chance to participate in major projects that would have been beyond our capabilities as a smaller private company.

How do you synergize your marketing and branding strategies of various products?

We sell products under a number of brands, the broadest being Spectra Precision itself. The Nikon brand is of course rightly famous and is carried by many of our optical products. And while SECO is our primary brand for generic surveying and construction accessories, we also sell rebranded accessories to many 3rd parties and many of our competitors pay us the compliment of selling our accessories with their own surveying and construction products.

How does Spectra Precision address the requirements for user-friendly and cost effective GIS/GNSS solutions?

Spectra Precision is focused on providing solutions that are easy to learn and use, and which are robust and reliable in the toughest conditions. So our R&D investment is focused around those product virtues, particularly those of simplicity and reliability. Some vendors rush to add more bells and whistles to their products, often making them more complex (and frequently doing so without actually adding features of real value to mainstream customers). We prefer to put our effort into features that serve to make our customers more productive, from the moment they open the box.

How do you see the growth of surveying and mapping market in near future?

The last 5 years have been more difficult for construction and surveying markets worldwide, with the multi-wave financial crisis causing a slowdown in market activity across the globe. But we see plenty of bright spots emerging and most of our key markets are now growing again, even those in Western Europe. Business momentum has been rising each month during 2013 and with the fit between our product portfolio and our customers’ requirements now better than ever, we are confident that we’re going to continue helping those customers work productively and accurately in future.
In order to solve the underlying problem, Korea MOLIT (Ministry of Land, Infrastructure and Transport) enacted a special act on cadastral resurvey, proclaimed this on 16 September 2011. With the implementation of this special act from 17 March 2012, a CRP (Cadastral Renovation Project) has been being promoted in earnest. Therefore, a multi-purposed control network should be firstly constructed to promote effectively on the CRP. The system of reference point for CRP has to be promoted by applying unified network of reference point based on the WGRS (World Geodetic Reference System) rather than applying by dual-reference points through surveying and cadastral surveying. MOLIT has performed a demonstration project for Digital Cadastral Construction from May 2008 to the end of 2012 for introducing the WGRS to the field of cadastral surveying and promotion of CRP. As a result of this project, in 2009, satisfactory 1600 reference points which have the accessibility, availability, good line of sight (sky-visibility) among cadastral triangulation point and cadastral control points distributed in nationwide were selected to maintain the cadastral control point based on the WGRS. The cadastral control network for CRP is composed of national reference point and cadastral control point. A national reference point is re-classified as CORS and MCP (Multi-purposed Control Point). It is judged that the cadastral control point firstly organizes the 1st grade network based on re-estimated reference point, and then, it is necessary for cooperation plan with the cadastral control points which are newly installed for the introduction of WGRS by a local autonomous entity.

To do this, the present investigation estimates some factors such as the present state of reference point, installation history, positioning accuracy, and utilization with regard to current-operating CORS, MCP and re-estimated reference point (RRP). Finally, this investigation proposes the construction of a cadastral control network based on the WGRS for promoting CRP well-matched to the Korean topography.

The main contents and methods of this investigation are as follows; firstly, the current statue of the CORS and reference point with regard to national reference point is analyzed. Secondly, the formation of cadastral control point, previous maintenance history and characteristics, utilization, and the correlation of national reference point, performance differences are analyzed for the connection with cadastral criteria. Thirdly, the linkage with national reference point is established for the efficient use of the construction of cadastral control network based on the WGRS. On the basis of previous estimation, the distribution density of reference point analyzed for CRP; contribute to systemize the construction of cadastral control network and utilization based on WGRS.

New strategies for construction of cadastral control network

National reference point and associated procedures

Currently, MOLIT has announced new government guidelines that cadastral...
The triangulation control network has been formed with the connection of CORS and MCP located throughout Korea. As a result of the analysis of the distance between points within this network, the maximum distance is approximately 430km while the minimum distance is about 0.005km. This investigation is to check the overall distribution of simplex network and distance between points. It is enable to be evaluated as just the geometric value because this is not applying for real surveying project. The average distance is about 14km.

Table 1: Analysis on distance between points per reference point

<table>
<thead>
<tr>
<th>Network Configuration</th>
<th>Region</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORS +MCP</td>
<td>Throughout Nation</td>
<td>Maximum distance</td>
</tr>
<tr>
<td>CORS + re-estimated reference point</td>
<td>(included Island)</td>
<td>Minimum distance</td>
</tr>
<tr>
<td>MCP + re-estimated reference point</td>
<td></td>
<td>Average distance</td>
</tr>
<tr>
<td>CORS +MCP + re-estimated reference point</td>
<td>Land</td>
<td></td>
</tr>
<tr>
<td>CORS +MCP</td>
<td>(excluded Island)</td>
<td></td>
</tr>
<tr>
<td>CORS +MCP + re-estimated reference point</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Establishment of the standards of acceptable accuracy

The accuracy of current cadastral surveying is classified with mainly three factors; the accuracy for primary control point surveying, surveying method and surveying equipment, the accuracy

The triangulation control network has been formed with the connection of CORS and MCP located throughout Korea. As a result of the analysis of the distance between points within this network, the maximum distance is approximately 430km while the minimum distance is about 0.005km. This investigation is to check the overall distribution of simplex network and distance between points. It is enable to be evaluated as just the geometric value because this is not applying for real surveying project. The average distance is about 14km.

Analysis on distance between points excluded island

The case of the exception for the reference point located in the main island such as Jejudo, Ulleungdo, Dokdo, and Baelyeungdo, the analysis on the distance between points of simplex network is shown in Figure 3.

In the comparison of distance between points from simplex network organized CORS and re-estimated reference point on the main land, the maximum distance is approximately 180km and the minimum distance is around 0.233km. From these, the average distance is calculated by 9.8km.

Density analysis by using distance between points

The cadastral control network proposed in this investigation used the CORS and MCP as a criterion among national reference points, and the cadastral control point re-constructed in 2009 is the key-point of investigation in terms of the construction of reference network. In order to analyze the national placing density of cadastral control network based on the WGRS, it should be inevitably estimated the network configuration and distance between points from CORS, MCP, and the re-estimated reference point. In this investigation, an acceptable accuracy has been computed by error propagation law; this is conducted in accordance with the order of primary consideration.

Analysis on distance between points included island

First of all, the distance between points located within the triangulation control network which has been constructed by CORS, MCP, and re-estimated reference point included at Jejudo, Ulleungdo, Dokdo, and Baelyeungdo has been analyzed. Figure 2 shows the analysis of distance between these points.

Figure 2: Analysis on CORS and MCP

Figure 3: Analysis on the distance of CORS and re-estimated reference point in main land
to restore the boundary on a map to ground boundary point, and the accuracy for maintenance of ground boundary point. The accuracy points mentioned above should have the consistency.

Numerical analysis to accuracy
When conducting on cadastral control point, the accuracy is defined to total station surveying. This is based on lateration, the accuracy to distance should be suitable for ±(5mm+5ppm) regardless of the type of cadastral control point.

However, the currently introduced surveying equipment has the higher accuracy than the one announced in regulation. Therefore, accuracy will not be an issue any more unless the artificial error is induced. When analyzing the accuracy of the distance, with the assumption of 2km average distance between cadastral triangulation control point, if the accuracy ±(5mm+5ppm) of the enforcement regulation of cadastral surveying is applied.

$$e = \pm \sqrt{5^2+(5 \times 10^{-6} \times 2 \times 10^6)^2} = 1.2\text{mm}$$

If the location of cadastral triangulation control point from CORS is determined with the accuracy by ±1.2cm, the accuracy of this point must have the level of ±3.2cm. Moreover, if in the conjunction with MCP, the accuracy by the level of ±4.4cm can be determined. In the case of cadastral supplementary control point, its accuracy can be considered by ±0.7cm under the same standards. If the location is determined through those connected with CORS, its accuracy is ±3.1cm. And then, in the location determination connected with MCP, the accuracy by level of ±4.5cm can be expected.

Analysis on regional reference network (Kangwondo)
The worst limitation, in terms of the construction of reference point, is the application of GPS affected on environmental effect. In the particular case of a forest or urban place, the construction of reference point network should be restricted due to the deficiency of the tracking number of the satellite. With the consideration of this viewpoint, the configuration density of reference point and surveying technique are considered depending on the characteristic of topography. The Kangwon province having the highest forest density is performed to the most frequently survey as the combination of GPS and TS. Due to this, it can be expected that this province will carry forward a CRP among the latest target area.

Considering the regional features, the average distance between reference points is approximately 8.7km, followed by the Article 9 (Section 1 No.2) of enforcement regulation on cadastral surveying, when using a precise macro meter having a standard deviation of more than ±(5mm+5ppm), the accuracy can be calculated as follows;

$$e = \pm \sqrt{5^2+(5 \times 10^{-6} \times 8.7 \times 10^6)^2} = \pm 4.4\text{cm}$$

Also, in the case of CORS or MCP, the accuracy is estimated by around 5.3cm. In accordance of the regulation of triangulation surveying the accuracy of the GPS receiver, ±(5mm+1ppm×D), the accuracy of GPS receiver itself can be estimated by about 1cm, when measuring from CORS or MCP, the accuracy is about 3.2cm, in the case of

Table 2. Analysis on accuracy in cadastral control point

<table>
<thead>
<tr>
<th>The type of cadastral control point and distance between points</th>
<th>Average distance(d) and composition of reference point</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadastral triangulation control point (2~5km)</td>
<td>if d=2km, CORS+Cadastral triangulation control point</td>
<td>Accuracy : ±1.2</td>
</tr>
<tr>
<td></td>
<td>CORS+Cadastral triangulation control point</td>
<td>$\sqrt{5^2+1^2+1^2} \approx 5.3$</td>
</tr>
<tr>
<td>Cadastral supplementary control point (1~3km)</td>
<td>if d=1km, CORS+Cadastral supplementary control point</td>
<td>Accuracy : ±0.7</td>
</tr>
<tr>
<td></td>
<td>CORS+Cadastral supplementary control point</td>
<td>$\sqrt{5^2+0.5^2} \approx 3.0$</td>
</tr>
<tr>
<td>Cadastral supplementary control point (&lt; 500m)</td>
<td>if d=0.05km, CORS+cadastral supplementary control point</td>
<td>Accuracy : ±0.5</td>
</tr>
<tr>
<td></td>
<td>CORS+Cadastral supplementary control point+cadastral</td>
<td>$\sqrt{4.5^2+0.5^2} \approx 4.5$</td>
</tr>
<tr>
<td></td>
<td>supplementary control point</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Establishment of cadastral control network based WGRS

<table>
<thead>
<tr>
<th>Promotion strategies</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data research to the performance of re-estimated reference point</td>
<td>• cadastral control point, the quality control of GPS measurement and conducting conformance test</td>
</tr>
<tr>
<td>the construction of cadastral control network for the linkage from CORS/MCP/re-estimated reference point</td>
<td>• classification of data issued in accuracy</td>
</tr>
<tr>
<td>composition between reference points and GPS surveying</td>
<td>• Design unified network with re-estimated reference point by considering the density of CORS, MCP</td>
</tr>
<tr>
<td>adjustment of national unified network and application plan for CRP</td>
<td>• back-up surveying for the precise linkages with CORS, MCP</td>
</tr>
<tr>
<td></td>
<td>• Carrying out national network by using precise network software such as GIPSY-OASIS/QOCA, GAMIT/GLOBK</td>
</tr>
<tr>
<td></td>
<td>• new construction of reference point through density analysis by MCP</td>
</tr>
<tr>
<td></td>
<td>• application plan for CRP</td>
</tr>
</tbody>
</table>

New construction of cadastral control network for CRP

Establishment of the standards

The unification between the geodetic and cadastral control point for successfully promoting of CRP in the near future should be firstly carried out adjustment of the unified network. To do this, systematic implementation strategies are required as follows.
the successive measurement of CORS, MCP and re-estimated reference point, the accuracy by 4.4cm is estimated.

New model for reference network

The most important factor with regard to construction of new network is the standards for accuracy notified special act on CRP. In the article of this act, in the acceptable range to linkages of performance test, the cadastral control point is ±3cm, and boundary point is ±7cm. According to the estimation of the average distance between points of simplex network organized from regional CORS, MCP, and re-estimated reference point, Seoulsi and 6 metropolitan cities have a shorter average distance than that of other provinces. Even the number of reference point is small compared to the area. The average distance of Seoulsi and 6 metropolitan cities is 6.3km and that of other provinces is 8.5km. Overall average distance is around 7.5km. The distance of the metropolis is longer by 1.2km than overall average distance. When conducting on the measurement of cadastral control point with average

### Distribution status of reference points

| CORS      | 12 | Max. distance | About 121.5km |
| MCP       | 175| Min. distance | About 0.12km  |
| re-estimated reference point | 228| Avg. distance | About 8.7km  |

### Composition of triangulation control network

- **Accuracy**
  - ±(5±5ppm)=about 4.4cm
- **CORS→re-estimated reference point**
  - \(\sqrt{3^2+4.4^2} = about 5.3cm\)
- **MCP→re-estimated reference point**
  - \(\sqrt{3^2-3^2+4.4^2} = about 6.1cm\)
- **CORS→MCP→re-estimated reference point**
  - \(\sqrt{3^2-3^2+4.4^2} = about 6.1cm\)

Notice: separation between available region for GPS surveying and not

---

**Figure 4: Analysis on cadastral control point in Kangwondo**

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distance of 7.5km, the accuracy of theodolite itself is estimated as follow.

\[ e = \pm \sqrt{(5 \times 10^{-6} \times 7.5 \times 10^6)}^2 = \pm 3.8 \text{cm} \]

In order to meet a acceptable accuracy (±3cm) of special act on cadastral resurvey, it can be implemented by reducing the distance between points with additional installation of reference point. As be calculated this theoretically,

\[ \sqrt{3^2 + (5 \times 10^{-6} \times 5.9 \times 10^6)}^2 = 30 \text{mm}, \; D = 5.9 \text{km} \]

Therefore, the average distance of network which consists of CORS, MCP, and re-estimated reference point should be within 5.9km to meet the acceptable accuracy in terms of construction of reference network. In the placing density of current MCP, 1200 reference points is installed through the grid of 10km×10km throughout Korea. Due to the increase of the convenience follow-up surveying, the placing density should be raised by the grid of 5km×5km.

However, the installation location of new reference point should be collected by considering on some factors such as geometric strength, the facilities of use, accessibility and convenience of follow-up surveying.

The analysis which is calculated in this investigation is just ot theoretical value; the distance between points of new installed point may be changed if regional distribution of reference point and its characteristics are reflected. However, the result of this investigation is able to utilize as fundamental resources in terms of construction of reference point. The average distance was calculated to 15 different regions. With regard to accuracy from these points, MCP was determined from the performance of CORS, sequentially MCP was applied to determine the re-estimated reference point. On all occasions, the accuracy by 7cm is not exceeded.

**Conclusion**

Firstly, the simplex network is constructed by linking 72 CORS, 1200 MCP, 1600 re-estimated reference point distributed throughout Korea. As a result of distance between points through simplex network, it can be identified that the average distance included island is about 9km; the average distance excluded island is around 7.7km. The acceptable maximum accuracy is estimated based on ± (5mm+5ppm) accuracy of theodolite surveying. The regional density of reference point should be increased for CRP. Secondly, the distance between points of metropolis and each province is calculated for considering regional characteristics. The average distance of metropolis is 4–5km, however, the case of reference point installed in forest or agriculture region such as Junlanamdo, Kyeongsangnamdo, Kanwondo has the lower density composited by 8–9 km average distance. Since acceptable accuracy is set-up at ±3cm for CRP with consideration on the national average distance of 7.5km, the installation density of reference point should be increased.

Thirdly, the average distance of network which consists of CORS, MCP, and re-estimated reference point should be within 5.9km to meet the acceptable accuracy in terms of construction of reference network. When considering the convenience of follow-up surveying and installation density of MCP the reference network of 5km×5km is suitable, but to do this, it can be estimated that more than 2000 reference points are necessary. And also, the installation location of new reference points should be collected through the facilities of use, accessibility and convenience of follow-up surveying.

**Table 4. Analysis on accuracy to average distance of reference points**

<table>
<thead>
<tr>
<th>Accuracy analysis to average distance (cm)</th>
<th>Accuracy</th>
<th>(\pm (5 + 1 \text{ppm}) = \text{about} 1.0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORS→ re-estimated reference point</td>
<td>(\sqrt{3^2 + 1.0^2} = \text{about} 3.2 )</td>
<td></td>
</tr>
<tr>
<td>MCP→ re-estimated reference point</td>
<td>(\sqrt{3^2 + 3^2 + 1.0^2} = \text{about} 4.4 )</td>
<td></td>
</tr>
</tbody>
</table>

**Table 5. Characterization of reference points in metropolis and each province**

<table>
<thead>
<tr>
<th>Region</th>
<th>Regional average distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kangwondo</td>
<td>about 8.7km</td>
</tr>
<tr>
<td>Kyeongkido</td>
<td>about 7.6km</td>
</tr>
<tr>
<td>Kyeongsangnamdo</td>
<td>about 8.7km</td>
</tr>
<tr>
<td>Kyeongsangbukdo</td>
<td>about 8.4km</td>
</tr>
<tr>
<td>Kwangjoosi</td>
<td>about 5.6km</td>
</tr>
<tr>
<td>Daegusi</td>
<td>about 5.7km</td>
</tr>
<tr>
<td>Daegjeonsi</td>
<td>about 7.5km</td>
</tr>
<tr>
<td>Busansi</td>
<td>about 5.2km</td>
</tr>
<tr>
<td>Ulsansi</td>
<td>about 7.8km</td>
</tr>
<tr>
<td>Incheonsi</td>
<td>about 7.8km</td>
</tr>
<tr>
<td>Junlanamdo</td>
<td>about 8.6km</td>
</tr>
<tr>
<td>Junlabukdo</td>
<td>about 7.6km</td>
</tr>
<tr>
<td>Chwoongchungnamdo</td>
<td>about 8.7km</td>
</tr>
<tr>
<td>Chwoongchungbukdo</td>
<td>about 9.6km</td>
</tr>
</tbody>
</table>

| Overall average      | about 7.5km               |

**References**


Outdoor mobile field robot navigation

This paper proposes a low-cost field robot capable of short-range field navigation, obstacle avoidance, color identification and spraying. Multiple micro-electro-mechanical sensors (MEMs) and multiple micro-controllers using a multi-layer fuzzy logic decision scheme were integrated to guarantee the autonomy of the mobile robot. Readers may recall that we published the first part of the paper in previous issue. We present here the concluding part.

Hardware and software implementation

This section presents the structure of a mobile field robot, including a robotic base and an embedded circuit board design.

Robotic base

The design of a mobile field robot must take into consideration its environment, the weight it carries and the size of the mobile robot. We utilized the speed difference between the two front wheels for steering control of the robot. The coupling mechanism design increases both the carrying capacity and the scalability. The robot, including its two motors and four wheels, weighs approximately 17.2 kg. With the addition of an embedded board, spraying module, battery and tow tractor, the total weight increases to 29.2 kg. The overview of the proposed mobile field robot is shown in Figure 7.

Sensors

The key components of the mobile robot were: the platform on which all modules are mounted; the multiple micro-controllers; the power circuitry; the motor controller; and finally, the sensors, including GPS module, Hall-rotary wheel encoders, an inertial measurement unit (accelerometer and gyroscope), an electronic compass, temperature/humidity (T/H) sensors, a laser range finder and a color sensor.

GPS module

The GPS module was produced by Parallax Inc. using an internal chip from the SiRF III chipset. The chip features 20 parallel satellite tracking channels for fast acquisition of National Marine Electronic Association (NMEA) data for vehicle navigation, telemetry or experimentation. The GPS module can interface with a microcontroller or even a personal computer (PC) via USB.

Odometry

Optical encoders are capable of calculating the distance a vehicle has traveled and provide information related to the direction of the vehicle. In this paper, optical encoders were used for secondary measurement of the vehicle’s heading and distance traveled. This data was used to supplement the information from the accelerometer and the gyroscope. Note that the sensors combined with IMU circuitry are capable of yielding far more accurate results and provide a more accurate estimation of the location of vehicles.

Electronic compass

This module employs a simple high-precision electronic compass capable of acquiring angles relative to North, according to the intensity of the magnetic field using BASIC programming language. In addition, it can make corrections anytime and internally set the desired bias angle to ensure that the vehicle maintains a fixed direction. The angle of direction is measurement in degrees functioning to determine the direction of a target and support the GPS module and IMU to accurately estimate the direction.
Accelerometer and gyroscope

Determining the relative location of autonomous vehicles is also necessary. The use of encoders to count wheel rotations is a good way to calculate distance and direction to determine the current position. Nevertheless, this method is susceptible to several sources of error including wheel slip. If wheels slip on the surface, the extra rotations result in inaccurate measurements of distance and direction. This paper used an accelerometer and gyroscope to determine the direction of the vehicle and support the GPS module to provide more accurate information. Semiconductor MMA7455L 3-axis digital output accelerometer is a low powered, micro-designed sensor capable of measuring acceleration along its X, Y, and Z axes. The module has a built-in ADC, low-pass filter, and selectable sensitivity range of ±2g, ±4g, or ±8g, which is perfectly suited to the proposed vehicle.

LISY 300AL is a single-axis high-precision gyroscope, capable of providing a maximum detection rate of 300 degrees/sec, maximum speed of 88 Hz and MEMs design of minimum size. Internally, the gyroscope sensor generates approximately 1.6 V on its analog when it is motionless. The output of LISY300AL was fed into a 10-bit analog to digital converter (ADC), with a high-speed (4 MHz) serial peripheral interface (SPI) and the signal pins capable of operating at 3.3 V and 5 V.

**Laser range finder**

The laser range finder is produced by Parallax company. The sensor module uses propeller 8-bit core chip and CMOS camera to detect the range, which is between the laser center to the object. The maximum measure range of laser range finder is 2.4 meters.

**Color sensor**

The color sensor employed in this paper was the TCS230 module produced by Parallax. The module integrates many electronic components, including a TAOS TCS 230 RGB sensor chip, a lens, and two current-regulated white light emitting diodes (LEDs). Those sensors are capable of measuring all visible colors and performing the task of color identification through BASIC Stamp.

**Embedded circuit board design**

Figure 8(a) illustrates a block diagram of the mobile robot system, comprising three micro-controllers, MEMs and spraying module. The first controller (micro-controller #1) receives digital data from the color sensor, T/H sensor, and spraying command. The second controller (micro-controller #2) receives signals from the gyroscope, electronic compass, laser range finder, and 2.4GHz XBee module (IEEE 802.15.4 protocol). The third controller (micro-controller #3) receives the GPS navigation data, accelerometer data and odometer data. Figure 8(b) shows the appearance of the embedded circuit board.

The GPS module is produced by Parallax Inc., using an internal chip from the SiRF III chipset. This module can interface with a microcontroller or even a personal computer (PC) via a Universal Serial Bus (USB) port. The IMU comprises an accelerometer, a gyroscope and an electronic compass, to collect data related to orientation and positioning. The laser range finder is used to detect the distance between obstacles and the mobile robot, to avoid collisions and maintain a fixed distance. A color recognition sensor is used for spraying. Data collected by each of the sensors is sent to the microcontrollers, where preliminary data processing is conducted. Data is stored with a heading identifier (ID) to identify the type of data. Thus, in writing the navigation algorithm, the micro-controller core was tasked with calculating the current location, based on the data collected from each sensor, and then conducting a dead-reckoning algorithm relative to the location of the target.

A simple command setup enabled the motor control board to change the speed of the direct-current (DC) motor at any time and receive data related to the current status of the motor, such as speed or direction data. The control board could handle a maximum current output of 30 Amps and a maximum input voltage of 35 V, with the provision of an internal 10 KHz pulse width modulation (PWM) current control, which was very convenient for the implementation of motor-speed control.

The proposed technique was implemented in an embedded system, which consisted of three micro-controllers (see Figure 8(b)). The programs of ‘color identification,’ ‘T/H detection’ and ‘spraying’ were written into the first micro-controller. The programs for ‘target tracking,’ ‘obstacle avoidance,’ and ‘decision mode’ were written in the second micro-controller. The programs for ‘motor controller’ and ‘dead reckoning’ in the navigation system were written into the third controller. The initial navigation parameters of the robot (including GPS data, landmark map, initial position of robot, obstacle position, relay position, etc.) and the fuzzy rule table were written to expand the memory module. Before the experimental testing, each sensor module had to be
tested to determine whether it could operate properly a priori in its integration with the mobile robot system. After the evaluation of the individual components was completed, the fusion-system testing began.

**Experiment results and discussion**

In many ways, farms are well-suited to autonomous guidance systems. For instance, the workspace does not change; landmarks may easily be installed in the corners of a field, which is then regarded as a stationary space. Crops usually include the same plants in the same places, which can be easily identified. In addition, with regard to such simple tasks as spraying and plant detection (identification), information given through the surrounding environment suffices to meet the same positioning demands. Even though the disadvantages of using mobile robot in greenhouses outweigh the advantages, adequate strides in related fields have been taken to justify proceeding with development. Therefore, the content of this section describes the testing process and evaluates the system performance of the mobile field robot, as shown in Figure 9. The electronic compass was mounted on top of the mobile robot to avoid electromagnetic interference. The T/H detection device was installed at the top of the water pipe. The servo motor module drives the pipe down, so that the T/H detection device could detect the value of T/H around the plant. The laser rangefinder was installed in front of the mobile robot and could perform horizontal rotation (about 180 degrees) through the servo motor module. Meanwhile, the laser rangefinder could be used for avoiding obstacles.

Testing was conducted in a constructed open area in Pingtung County, Taiwan. There were seven GPS satellites observed in the sky. For movement in an open area, the robot moved around the rectangular lawn in front of an apartment building at the National Pingtung University of Science and Technology (NPUST), Taiwan. The selected test area was approximately 20 meters square. The circumference was 70 meters, with ‘A’ as the starting point and ‘B’ as the endpoint. In this experiment, the locations of eight points were measured and recorded in advance within the robot’s system. A path was then planned with these points known beforehand. The robot moved clockwise based on the planned path, with each corner set at 90 degree angles. It was necessary to set a range to determine whether the robot reached the landmark, and the radius was set at 1.25 m. As long as the robot was within range of the landmark, it was considered to have reached the target landmark and could move toward the next.

Two experimental scenarios were developed and demonstrated. In the first scenario, the functionality of autonomous navigation of the mobile robot was tested. The second scenario involved the mobile robot navigating in the presence of obstacles and plants. The user could set the desired path, the locations of obstacles and plants and the color value. A flow chart of the program is shown in Figure 10.

The data (desired color range, planned path and location of landmarks) needed to be recorded before starting the mobile robot. Once the robot detected the desired color values, the T/H sensor module was then used to detect the temperature and humidity values around the plant. If the T/H value was below the desired value, the spraying operation was performed using that module. In addition, the laser range finder was employed to detect obstacles in front of the robot. After the process of color-detection and obstacle-avoidance, the mobile robot moved toward the nearest landmark. If it moved into the range of the landmark, the next landmark became the desired location.

**Scenario 1: Autonomous navigation test**

The purpose of this experiment was to test the ability of the mobile robot to follow a path, using its IMU component or its electronic-compass module in conjunction with the GPS module and the odometer, through a proposed scheme. In the setup of the experimental parameters, it is necessary to calibrate the gyroscope and accelerometer before its use. This could be done at startup by making sure the gyroscope and accelerometer are...
The average positioning error with and without (w/o) GPS is demonstrated in Table 6. By referencing the estimated position and the desired positioning data, the position error could be calculated. From Table 6, it can be seen that the adoption of the GPS plus dead reckoning method with the multi-layer fuzzy control system resulted in the lowest degree of positioning error.

### Scenario 2: Obstacle avoidance and plant-spraying tests

The second scenario was conducted in a field in which the robot was required to spray and identify a colored object when it moved. When objects were detected, the robot stopped and sprayed them, using a sprayer. While moving, the robot followed a planned path. Colored objects were placed near the planned path to test the detection performance of the robot. The functions of obstacle avoidance and plant spraying were tested in the outdoor environment. The information regarding the locations of obstacles and plants were recorded in the memory module of the mobile robot beforehand. After 10 testing, the average path of motion for the robot was as demonstrated in Figure 12 (The blue dot represents an obstacle; the pink dot represents the plant.). As is shown, the robot stopped where it encountered the colored objects and sprayed them. In addition, the mobile robot avoided the obstacle successfully. However, the robot could not reach into the range of landmarks successfully.

### Conclusions

This paper proposes a low-cost microcontroller, in conjunction with an MEMs component, to produce a multi-sensor embedded navigation system for implementation in a small mobile field robot. A multi-layer fuzzy system was utilized in robot navigation, spraying and obstacle avoidance. The use of the proposed decision scheme could enhance the positioning accuracy in both $X_e$–axis and $Y_e$–axis directions, to 0.46 m and 0.19 m with 0.2 m/s, respectively, over uneven pavement and with known landmarks.

In addition, the positioning accuracy effect of the mobile robot in the presence of different sensor combinations was analyzed. Although the adopted IMU sensor resulted in accumulated positioning errors, the precision of positioning was significantly improved by adjusting the scale factor and bias using software and odometry. The navigation system was equipped with GPS/IMU/odometry sensors, which could cause the positioning errors in both the $X_e$–axis and $Y_e$–axis directions to reach 0.76 and 1.43 meters, respectively, at a speed of 0.2 m/s. Overall, this system was flexible in combining different sensor elements for navigation, and also allowed for installation of the different brand sensors to an embedded board.

The proposed mobile field robot succeeded in detecting and accurately identifying objects, as well as spraying, during experiments in a field. The total cost of the robot was approximately US$ 930, including design, implementation and system integration, which was inexpensive considering the quality of the components used. This study implemented the concept of a multi-sensor embedded system in a mobile gardening robot, which may be valuable for future applications in greenhouses.

### Acknowledgements

This work has been supported by the National Science Council, Taiwan, Republic of China, under grant NSC 101-2221-E-020-018.
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Uttarakhand is in absolute shambles. Disaster, with most people calling it more manmade than natural, has exposed the fragility of this beautiful yet ecologically vulnerable region. Untold and unimaginable damage has been done with surging rivers and flash floods bringing death and destruction together. Glaring manmade gaps and inefficiencies have been identified and highlighted. All of this has left the State, its people and the citizens of our country traumatized.

Crisis in focus

As Uttarakhand completes its first month after the recent disaster, it is amply clear that this is a huge moment of grave crisis for the State. This tragedy, the biggest ever to hit Uttarakhand, has brought into sharp focus the fierce debate around environment, development, governance, politics and disaster management. Though the fury of nature has been unprecedented, many questions are being asked about the role of the State Government. These questions, based on equal doses of frustration, sadness and anger, are mainly being raised about the lack of disaster preparations and the development model pursued by the Government.

By now several facts are well known. The Uttarakhand Disaster Management Authority, constituted under the Chairmanship of the Chief Minister, has had no meetings since the past six years. Successive CAG reports have made scathing remarks on the lack of disaster management preparations in the State. Indiscriminate mining, haphazard urbanization, rampant cutting of trees and forest covers, use of dynamites for road construction, encroachments, buildings, hotels, guest houses and travel lodges on the river bed, too many hydropower projects, changing river courses, poor structural safety – this was clearly a Himalayan tsunami waiting to happen. Locals in the affected areas claim that this is only the trailer of the massive destruction that is lurking in this region of the country. Many others are calling it a ‘Human Tsunami’.

Challenges being faced

Uttarakhand is prone to frequent flash floods, landslides and cloud bursts. The mountain ranges are relatively new. Climate changes are impacting rainfall and cloud bursts in the Himalayan region, which have already seen increase in temperature that are 2-3 times higher than the average global temperature rise of 0.9 Degrees C. Against this background, the State has miserably failed to develop any systems of early warning, forecasting and disseminating rainfall and landslide related information. Technology is available that can predict cloud bursts at least three hours in advance, but no such sophisticated equipment is used in the State.

There are other challenges too. Uttarakhand is politically as fragile as its mountain ranges. With six different individuals holding the Chief Minister’s position during the last 13 years, since the formation of the State in 2000, the average tenure of each has been two years.
This has resulted in lack of continuity and failure in getting a firm grip on the issues plaguing the State. These figures look even more ominous when compared with Himachal Pradesh, Uttarakhand’s Himalayan neighbor. Himachal Pradesh has had five chief ministers during the past 60 years. Only two, Virbhadra Singh and Prem Kumar Dhumal, have held the reign of the State since the last 20 years.

The political fragility has resulted in ad hoc and unplanned development. Successive governments have failed in creating any sort of medium term or long-term plan or vision for the State. Most decisions appear unconnected and lack coherence. They are mostly random in nature and pander to the demand of the moment. Political instability and inexperience have also resulted in lack of articulation about the firm and correct position to be taken by the State in several matters that are most important for them. Programs and policies are started but often are not completed due to frequent changes. In this scenario, how is sustained development possible?

Who is responsible?

Clearly the major defaulter is the political leadership of the State and the Government of the day. The political leadership in Uttarakhand, with the exception of a few distinguished and sincere politicians, is widely perceived as being either corrupt and/or incompetent. Internal squabbles are hardly leaving any time for senior party leaders to give any quality time for public issues, strategic planning and the long-term development of the State. Just before the massive disasters struck Uttarakhand, five MLAS of the ruling party were camping in Dehradun, the State capital, for few days protesting against their own Government and complaining about the lack of development in their respective constituencies. Bureaucracy is being adversely affected. When politicians frequently complain that bureaucrats are not listening to them and the bureaucrats retort that the politicians do not let them work, the leadership deficit at the highest levels becomes clear and apparent.

The Government is now staring at mammoth challenges. They need to act and act quick on multiple fronts. As Uttarakhand continues to grapple with inclement weather affecting relief operations, the next set of action items need to be ready. Detailed impact assessment of affected areas and the learning’s from this tragedy need to be documented. Immediate compensation of the locals needs to be finished on a war footing. Roads and bridges need repairs. Hospitals and food supplies need strengthening. Livelihoods dependent on the Char Dham Yatra need to be restored. It’s a long list that requires serious planning, coordination, strategy and execution.

What next?

Where does Uttarakhand finally move to from here? This is not only a time to mourn, but also to reflect and create a blueprint for its future and destiny. The policy makers can move in any of the two directions – either follow the path that they have taken earlier and rebuild Uttarakhand on the poor foundation of unscrupulous
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and unplanned development. Or take a radical, new path and come up with a unique, innovative and inclusive model of development built on the foundation of modern disaster management techniques and equal concern for the environment and livelihoods. This needs to be the starting point for this development strategy. This path will further require an open mind, belief in science and technology, exemplary leadership and genuine compassion and empathy for Uttarakhand. This is where the whole concept of exceptional leadership comes in.

As the ones who have lost their loved ones try and desperately get their lives back on track and the others limp along, the question that still haunts many is what next? With confidence in the political class at an all-time low, the rehabilitation hopes of the people of Uttarakhand are very low. Though the Government has announced relief and compensation measures, this is clearly not enough to rebuild shattered lives and reestablish broken homes. Much more needs to be accomplished to get things done and to inspire hope for the future. Only exceptional leadership can turn this around.

Defining leadership/Leadership in question

There are hundreds of leadership definitions. In this time of incomprehensible crisis, the one that appeals the most to me are the famous words of John Quincy Adams, the sixth President of the United States of America - “If your actions inspire others to do more, learn more, do more and become more, you are a leader.” The level of leadership that Adams had in mind when he said these famous words is the only level of exceptional leadership that can take Uttarakhand ahead. Politicians and bureaucrats can make plans and announcements, but without exceptional leadership Uttarakhand would continue to lick its wounds and forever feel sorry for itself.

What is the starting point for this exceptional leadership? This has to be leadership that can act quickly and is able to create that sense of extreme urgency. There needs to be leadership that operates on strong principles of alliances and partnerships, and is able to motivate various agencies and institutions to come forward and support the rebuilding of the State. On a sensitive note, this has to be leadership that can deeply feel the pain of the people who have perished and others who have lost everything. Is this level of exceptional leadership possible in today’s cut-throat and highly competitive political environment in the State? The non-believer would obviously say no, but in this hour of extraordinary gloom and misery, it is only outstanding actions and exceptional leadership that can heal Uttarakhand and make it move ahead.

What should the leadership in Uttarakhand be doing right now? There are three things to focus on. Creating a vision, communicating that vision and executing the vision is what the leadership should concentrate on. Working on multiple fronts, the leader will have to inspire the millions of ‘Uttarakhandis’ and the rest of the nation who are all looking up to him for creating a holistic and consolidated strategic long-term rehabilitation and development plan for the State. Integrity, competence and plain old hardwork are just few of the components that are needed for exceptional leadership to have a long-term impact on life and livelihoods in Uttarakhand.

Blueprint of development

Why is creating a vision necessary? In the Cold War era of the 60s, the Americans were lagging behind the Soviets. John F. Kennedy, the then US President, needed a vision to inspire his country and said in the Congress - “I believe that this nation should commit itself to achieving the goal, before this decade is out of landing a man on the moon and returning him safely to the earth.” Critics called it fantasy while many others termed it pure lunacy. Kennedy’s dream was fulfilled when on July 20, 1969 the Apollo 11 Commander Neil Armstrong stepped foot on moon and said, “That’s one small step for man, one giant leap for mankind.”

If the Americans could create this extraordinary vision more than 50 years ago, why can’t our leadership get inspired and create a vision for the rebuilding of Uttarakhand? Leadership needs to come out with a vision that is clear and articulate. It needs to be simple, inspirational and time bound. In the absence of a vision, as a State, Uttarakhand will once again fail and falter, as it will operate on a day-to-day basis without any long-term goal or plans.

Once the vision is clear, it needs to be clearly communicated and understood. The fulfillment of the vision for Uttarakhand should get utmost priority over everything else that matters. This will require an iron will and the ability to take bold steps at every moment making steady progress towards achieving that vision. The people of Uttarakhand would need to have a deep faith in the vision and would have to truly own that vision. The ability to inspire others would only come with exceptional leadership.

Implementation of goals

How will the vision get fulfilled? This is where the ability to conceptualize, to create institutional frameworks and to deliver outcomes comes in. Creation and communication of the Uttarakhand vision needs to be backed up with execution and results on the ground. The bureaucratic machinery needs to be energized and organized. Deft political handling of opponents within and outside the party needs to be undertaken as a preventive measure. All this would require exceptional leadership.

The cynic, as always, is bound to sneer and call the exceptional leadership dream for Uttarakhand equivalent to making castles in the air, while the optimist agrees to move on the path towards a safer and new Uttarakhand. But for the State to feel optimistic there needs to be an exceptional leader to hold her bruised hands and show her the path. Time alone will tell if Devbhoomi Uttarakhand, the mystical land of gods, legend and lore, was fortunate during its worst times to have had that exceptional leadership.
The use of GIS to forecast tourism demand

This study shows that the full potential of the Huff model has not been recognized yet

Most applied methods to determine the tourism demand depend on the availability of demographic data, social and economic characteristics of tourists, tourism customs, the quality of tourist activities and facilities, and other foundations such as the capacity of the tourist destination, and its accessibility. So, a tourism site must be designed in accordance with the standards and regulations of great importance in the protection of environment resources, and to develop appropriate plans to meet the expected demand for tourism. The urban planning optimal tourism sites take into account the number of tourists forecast, whenever available accurate data on flow of tourists in the area, which makes tourism development more accurate and logical. Because such information can often be unavailable or inadequate to forecast tourist numbers; due to lack of monitoring mechanisms set up, tourists and limitations add to the cost and effort and duration (Ghoneim, 2003). Define and analyze trade areas help forecast tourism flows.

The study goals to achieve the following:
1. Develop an approach for forecasting tourism demand by GIS.
2. Identify the different factors and variables that play an important role of spatial interaction related to tourism demand.
3. Design the necessary database for the model using GIS for a site with real data (Al-Uqair).
4. Implement the automated model, checking its validation, and discussing the possibility of generations.
5. Determine the geographic distribution pattern of the model output and discussing it in the light of the pros and cons of the automated application of the model.

This study uses (ArcGIS Business Analyst), since these systems are designed to analyze and interpret spatially, in addition to calibrating the Huff model to measure tourist numbers through a real case study (Al-Uqair). There are several reasons behind the selection of Huff model in this study. First, the form is theoretically attractive; as the logical underpinning of the model makes sense and the output can be communicated easily and understandably. Secondly, the model is relatively easy to make operational. The necessary computations are straightforward once the values of the variables and parameters are specified. The third reason for the model’s popularity is its applicability to a wide range of problems and its ability to predict outcomes that would be difficult, if at all possible, without the model. Despite the general applicability of the model, it has not always been employed correctly. Furthermore, the full potential of the model has not been realized.

Study background

David Huff introduced his model in 1964, which takes into account the number of consumers, the attractiveness of business centers, and the distance and competing commercial centers that predict consumer behavior spatially. Huff model is derived from the theories which are based on spatial analysis which are based on the principle that the prospect of a buying or visiting consumer to a particular site depends on the distance and the attractiveness of the site and the distance and attractiveness of competing sites. This model is used in spatial interactions researches (Huff, 1964).

Trade areas analysis models provide great potential for the formulation and appraisal of geographic business decisions. The Huff
model was widely used by business analysts in the public and private sectors as well as academics across the world. The popularity of the model increased with the development of the GIS technology. For example, the model can be used in the field of trade for the following purposes: Assessing market prospects; identifying and analyzing trade areas; assessing market penetration; estimating the economic impact; forecasting consumer choices in shopping; describing the distribution of consumers geographically, and estimating the sales size for the current and potential selling outlets (Huff, 2008). As the case in the trade field where the commercial market penetration is forecast through geographic scope, the same idea could be used to analyze the potential tourism demand, as a commodity subjected to the supply and demand laws.

Using Huff Model for tourism demand estimation

The actual reality theories of tourism demand as indicated in Kafi’s study (2008) are as follows: (1) the number of inbound tourists is directly proportional to the number of residents and the intensity of their movements; (2) the number of inbound tourists is directly proportional to the relative attractiveness of the tourism destination; (3) the number of inbound tourists is inversely proportional to the distance to the destination (accessibility). This takes into account the competition factor, where the distribution of potential tourists to competing destinations is taken into account according to the distance. The attractiveness of each competing destination plays an important role in the distribution of the number of tourists, and the attractiveness of any tourist destination depends mainly on the available attracting factors, such as the prevailing natural environment, the type of services available, and the image of a destination that affect the tourist when choosing alternatives. The number of tourism facilities in any tourist destination is a reflection of the attractiveness of this destination; thus, when the attractiveness increases, the destination’s facilities increase. In other words, it can be said that tourist destinations that have the greatest facilities have the greatest degree of attractiveness.

The Huff model includes many factors and variables affecting the tourism demand which are clarified by previous studies to controllable and non-control variables. The controllable variables could be processed by decision-makers, such as advertisement, tourism packages, prices, and provision of tourism services and infrastructure development. The non-control variables are generally beyond control, such as natural tourism potentials, the archaeological and historical factors, population distribution, distance, and competition. Therefore, the application of the Huff model to forecast the tourism demand requires compiling a list of specific factors. The adopted factors in this study are limited to the significant ones such as spatial vicinity, area, and the availability of natural potentials and other tourist attractions, based on the Hudman study (Hudman, 1980). Both factors are a form of data that will feed the model.

The Huff model is based on the theory that when someone is facing a range of alternatives, the probability of selection is directly proportional to the tangible benefit of that alternative, so the selection behavior is mathematically referred to by \( P(\bar{i}|j) \). As a result of the alternative selection process, trips are distributed among different tourism destinations. So, the Huff model will be used to measure the distribution of tourists. The factor of distance traveled by tourists to reach the tourism attractions could be used as a variable. And the distance will be considered a main variable in this study, which is measured by the duration of the trip. Given the importance of the time it takes to travel between the places of residence to the tourist destination, the trip duration gives an overview of the accessibility, the traffic volume, and the status and quality of available roads. The tourist site area reflects the attraction power, i.e., the developed area comprising tourist facilities such as accommodation, resorts, restaurants, parks, landscape, and waterscape related to leisure and entertainment. Table (1) indicates a list of tourist demand factors, variables and measuring units, which will be taken into account in this study for Al-Uqair site and competitive tourist destinations. Spatial vicinity factor is inversely proportional with tourists, while the other factors of area, availability of tourism potentials, and the surrounding attractions are directly proportional to the number of tourists.

Mathematical formulation of the Huff Model to forecast tourism demand

A phase of analyzing the tourism demand behavior mathematically by linking the effecting factors and variables. It is called ‘the diagnostic since it explains how factors can be linked together through the Huff model. Therefore, the use of the Huff model in this study is as a mathematical equation linking the factors influencing the tourism demand. The Huff model by linking the above mentioned tourism demand factors can be explained by re-explaining the equation number (1) mathematically, as follows:

\[
P_\theta = \frac{\sum_{\bar{i}=1}^\alpha A_\theta^\bar{i}N_\theta^\bar{i}T_\bar{i}^\theta D_\theta^\bar{i}}{\sum_{\bar{i}=1}^\alpha A_\theta^\bar{i}N_\theta^\bar{i}T_\bar{i}^\theta D_\theta^\bar{i}} \tag{1}
\]
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* Work mode and accuracy

**SBAS differential mode**
(Satellite Based Augmentation System)
(GAGAN / WAAS / EGNOS / MSAS)
--- submeter level (with India GAGAN)

**Static and Fast Static mode**
--- mm level

**PPK mode**
(Post-processed Kinematic)
--- cm level (at good condition)
--- submeter level (at common condition)

**CORS network mode**
(Continuous Operation Reference System)
--- $\leq 0.5$ m (Single frequency)
--- $\leq 0.2$ m (Dual frequency)

* Accuracy and reliability may be subject to anomalies due to multipath, obstructions, satellite geometry and atmospheric conditions.

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Whereas:
\[ P_{ij} \] = the probability of tourism demand in area \( i \) frequently visiting the tourism destination \( j \)
\[ i \] = area originating tourists (the source)
\[ j \] = the destination (endpoint)
\[ A_i \] = area variables in tourism destination \( j \)
\[ N_j \] = variables of available natural potentials in tourism destination \( j \)
\[ T_j \] = variables of tourism attractions in tourism destination \( j \)
\[ \gamma_i \] = area variables coefficient
\[ \gamma_j \] = variables coefficient of available natural potentials
\[ \gamma_{ij} \] = variables coefficient of other tourism attractions
\[ D_{ij} \] = accessibility to tourism destination \( j \) for tourists in area \( i \) and measuring it with time unit
\[ \lambda \] = distance variables coefficient
\[ n \] = number of tourism destinations

In this stage, the original Huff model is being calibrated, tested and validated, as the resulting standard model can be naturally distributed, not with high level of statistical implications. All this is done in the light of verification by comparing the results of calibration with real statistical data.

The calibration process of the Huff model’s variables coefficient requires calculating the data of tourism demand probabilities (ratios), its referred to by \( P_{ij} \) in equation. The calculations of tourism demand probabilities data are based on choosing appropriate initial values - an approximate weights for key variables coefficients (\( \gamma, \lambda \)) as a preliminary stage. Therefore, the initial coefficients values are dubious; due to the inability to determine the statistical significance of the variables.

The main two variables (distance, area) influencing tourism demand directly can be identified as follows:

First: The area represents the tourism attraction variable \( A_i \). And in the beginning, a coefficient value was proposed (\( \gamma_i \)), which is (1), as neutral value.

Second: The distance represents the tourism direct variable \( D_{ij} \), the distance between the tourist’s place of residence \( i \) and destination \( j \). The value of the distance measured by the identification coefficient \( R^2 \); (5) the estimation errors should be statistically distinctive, which is done in the light of verification by comparing the results of calibration with real statistical data.

Modified weights of the variables coefficients \( \gamma_i, \gamma_j, \lambda_i, \lambda_j \) result from the Huff model calibration process for the tourism demand variables entered in the model which give more accurate results and closer to the data that have been monitored in the field. After verifying the efficiency of statistical calibration, the model can be applied to forecast the probability of tourism demand in any tourists’ exporting area \( i \), in case of choosing any tourism destination \( j \), according to the following final equation:

\[ \hat{P}_{ij} = A_i \cdot D_{ij} \cdot T_{ij} \cdot \frac{1}{\sum_{j=1}^{n} N_j \cdot T_j \cdot D_j} \]  

After statistically determining the criteria, the model can be used to forecast the consumer spending on a certain product provided by the store \( j \), which is located in a specific geographic area within the study area, according to the following formula:

\[ E_{ij} = (P_{ij})(B_j) \]  

The total sales in each store in the geographical area can be determined by adding the expected expenses in each geographical area for all stores, according to the following equation:

\[ T_j = \sum_{i=1}^{n} E_{ij} \]  

The market share of each store in the study area equals to the total expected sales of each store divided by the total sales of all stores, as follows:

\[ M_j = \frac{T_j}{\sum_{j=1}^{n} T_j} \]
Steps of determining the study area

The first and most important step after obtaining the relevant accurate data is to define the tourism impact area as it should be. This stage is very important due to the impact of geographic extension on determining the nature and volume of data that should be collected in addition to any conclusion to be reached based on the analysis of these data. The steps used to determine the impact area are illustrated as follows:

1. Locate Al-Uqair and similar tourism destinations, in addition to the road network and surrounding communities within the study area, which was identified in the third chapter of this study.
2. Determine the tourism impact area which depends on the distance traveled by tourists to reach the destination, assuming that the distance ranges from (100 km) to (400 km). This type of tourism involves a large group of local and regional tourists, and classified as medium-range tourism (Kafi, 2008).
3. Define the borders of the initial impact area, which usually reflects the natural or human barriers that hinder tourism movement between specific areas, and impedes movement between the defined area such as international borders, seas, mountains, and road network.
4. Draw the borders of common areas of influence, and this is the initial approximation to the impact area.
5. Divide the initial impact areas to smaller geographical units through which tourism statistics data could be collected. To determine these smaller geographical units, the previously identified sub-regions are usually used by some entities such as the Department of Census which divides the regions into different levels of spatial details.
6. Obtain the available tourism statistics for each sub-region which include the number of one-day trips, excursions, leisure trips, marine trips, the spending on marine activities, and the required location data (coordinates of latitude and longitude) for mapping each sub-region.
7. Modify the impact area if necessary to reflect the sub-region boundaries.
8. Collect data reflecting the relevant competitiveness of each tourism destination within the impact area such as the area, number of resorts and other tourism attractions.
9. Determine the distances or travel time between the sub-regions and all tourism destinations within the impact area.

Application on study case

Geographical location

Al-Uqair is located on the Gulf Sea coast in the Eastern Province of the Kingdom. It is located within Al-Ahsa administrative area. Al-Uqair coast extends between the latitudes (24° 25' N) and (44° 25' N) to the north, and between longitudes (50° 08' E) and (24° 50' E) to the east. It is 50 km long and 10 km wide inward. See Figure (2).

The tourism significance of Al-Uqair beach lies in its expected role. Its natural components imposed the merging of this beach on the national tourism map in Saudi Arabia, in addition to the likelihood of attracting a large number of visitors and tourists in the future. This means that the development of Al-Uqair beach will relieve pressure on other beaches in the eastern region. Moreover, new investment opportunities, and other economic and social returns are expected (SCTA, 1425).

In step (1), Al-Uqair location and other similar tourism destination were determined. There are some tourism centers in the eastern coast which were developed partially or completely, such as Al-Jubail Industrial Corniche, Al-Dammam Corniche, Al-Khober Corniche, Al-Azizia and Half Moon. Similar destinations are located in Al-Dammam, Al-Khober, and Al-Jubail, and can be considered competitive centers for Al-Uqair beach, Figure (3).

Step (2) describes the three competing tourist destinations for Al-Uqair and their areas of impact. They are forecast by circles of (400 km) radius, as shown in Figure (4).

Step (3) shows the final boundaries of the tourism impact area, as shown in figure (5), after being adjusted in accordance to the provincial boundaries. The aim is to facilitate access to the available statistical tourism data at the district level (polygon).

Figure (6) shows the population clusters with over (2,500) people, which is linked to the road network. Their total number reached (232) points, administratively distributed on (16) districts within the borders of the impact area. It is clear that the pattern of the spatial distribution of population points ranges between the clustered and random pattern.

Using cellular representation

By covering the impact area with cellular network helps to calculate the area with square kilometers per unit (cell) in the

Figure 1: Workflow of forecast tourism demand by model builder.
Figure 2: AL-Uqair Geographical Location
Figure 3: Al Uqir and similar tourist destinations
map. It also helps in measuring the distances required by the Huff model. The selected cell size in this study is (50 X 50) square kilometers, to be compatible with the geographic data representation level at the regional level, and takes into account the spatial distribution pattern of communities. Thus, each cell could contain the largest number of communities, considering the center of each cell to be the distance measuring point to various tourist destinations.

148 cells were excluded because they do not contain any community. So, the total number of cells that contain population clusters is 79 cells within the impact area, as shown in Figure (7).

**Concluding the Characteristics of the Tourism Impact Area**

Table (2) summarizes the geographical characteristics of the impact area by using the cellular model. It is clear that the tourism market options are limited to three destinations competing on an area of 197.500 square kilometers, and 232 population clusters in (16) districts.

Tourist properties may vary among tourism trips exporting provinces depending on the differences in cultural and socio-economic backgrounds, besides the provided recreational activities. Table (3) shows the data of trip source, the number of one-day tourists, the purpose of trips whether for holidays and recreation or voyages; and the tourist spending on marine activities geographically distributed on (16) provinces. It is notable that the pattern of data distribution in the source regions, within the impact area, has no effect on the calibration of the model. However, its role is limited to determining the characteristics of potential tourists.

**Analysis and discussion**

There is an important factor to determine the impact of any tourist center on the communities which is the availability of other similar entertainment centers. Usually the proximity of tourist destinations to population clusters impacts the beach visitors. Although all destinations seem equal, the central tourism destinations are easily accessed and are likely to attract more tourists compared with other destinations. The attractiveness of tourist destinations, in most cases, is determined according to the variables that can be controlled by development officials as illustrated in the previous chapter. However, the variables used in this case study are limited to - spatial proximity, the area of the destination, and the availability of natural potentials and surrounding tourism attractions.

Table No. (4) clarifies the characteristics of three tourism destinations: Al-Dammam; Al-Khober and Al-Jubail. It is clear that Al-Khober covers the largest area, followed by Al-Dammam and then Al-Jubail. Al-Jubail is featured by the available natural components such as pure sea water, and sandy beaches. Other tourism attractions are equally available in all destinations. Al-Uqair data was limited through the tourism development scheme and the results of the model’s coefficients calibration will be applied later.

### Table 2: Geographical characteristics of the impact area using the analysis network

<table>
<thead>
<tr>
<th>Geographical Characteristics</th>
<th>Measurements (quantities, length, area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North and south</td>
<td>(900) km (the furthest boundary point)</td>
</tr>
<tr>
<td>East and west</td>
<td>(850) km (the furthest boundary point)</td>
</tr>
<tr>
<td>Total area</td>
<td>(197,500)km 2</td>
</tr>
<tr>
<td>Number of population clusters</td>
<td>232</td>
</tr>
<tr>
<td>Number of districts</td>
<td>16</td>
</tr>
<tr>
<td>Number of impact area cells</td>
<td>227</td>
</tr>
<tr>
<td>Number of inhabited cells</td>
<td>79</td>
</tr>
</tbody>
</table>
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Suzhou FOIF Co., Ltd.
Calibration of the Huff model coefficients to forecast the tourism demand

After collecting the tourism demand potentials’ data, which is necessary to calibrate the coefficients of the Huff model, equation (4.10) can be applied which represents the linear version of the Huff model. Table No. (5) shows a sample of regression equation data, including 9 data cells. The third column shows the dependent variable, representing the tourism demand potentials’ data divided by its geometric mean. Columns 4-7 show the independent variables arranged successively as follows - distance, area, natural components, tourism attractions, divided by its geometric mean.

Table (6) shows four attempts to calibrate the model. It used another type similar to the multiple regression called the Stepwise Regression, which determines the importance of each independent variable in explaining the change that occurs in the dependent variable. The ratio of change is ordered based on the importance of each independent variable. The order starts from the highest percentage, or the most important variable, and ends with the lowest ratio or the least important variable in explaining the change that occurs in the dependent variable. The fourth statistical model explains the four independent variables (*) (96%) of the variance in the value of the dependent variable (**). The variable of proximity is the most important variable to forecast the attractiveness of the tourism destination selected, representing (69%). On the other hand, the remaining tourism attractions variables have also high statistical significant.

Coefficients estimation

Table No. (7) shows the forecasted coefficients, used as adjusted weights for the tourism attractiveness variables coefficients entered in the Huff model to forecast tourism. The distance coefficient weight \( \hat{\alpha} \) represents the value (-2.86), and minus sign indicates diminishing the impact with increasing distance. While the

### Table 3: Tourists source regions data in impact area in 2007

<table>
<thead>
<tr>
<th>S</th>
<th>Network code</th>
<th>The district (source) (i)</th>
<th>The number of: One-day trips</th>
<th>Tourism trips</th>
<th>Leisure tourism trips</th>
<th>voyages</th>
<th>spending on marine activities (SR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.3</td>
<td>Hef AlBatin</td>
<td>0</td>
<td>173208</td>
<td>38344</td>
<td>980</td>
<td>10257020</td>
</tr>
<tr>
<td>2</td>
<td>12.3</td>
<td>AlKhafji</td>
<td>1721</td>
<td>12560</td>
<td>0</td>
<td>1050</td>
<td>535</td>
</tr>
<tr>
<td>3</td>
<td>5.1</td>
<td>Qariat AlOlya</td>
<td>0</td>
<td>230</td>
<td>150</td>
<td>89</td>
<td>40125</td>
</tr>
<tr>
<td>4</td>
<td>5.12</td>
<td>AlNe’ airiah</td>
<td>887</td>
<td>50697</td>
<td>48686</td>
<td>1300</td>
<td>13023505</td>
</tr>
<tr>
<td>5</td>
<td>7.15</td>
<td>Al-Jubail</td>
<td>58000</td>
<td>146000</td>
<td>41000</td>
<td>80300</td>
<td>10967500</td>
</tr>
<tr>
<td>6</td>
<td>7.17</td>
<td>Ras Tennourah</td>
<td>0</td>
<td>2000</td>
<td>0</td>
<td>1100</td>
<td>535</td>
</tr>
<tr>
<td>7</td>
<td>8.16</td>
<td>Al-Qatif</td>
<td>0</td>
<td>7000</td>
<td>0</td>
<td>1294</td>
<td>535</td>
</tr>
<tr>
<td>8</td>
<td>8.17</td>
<td>Al-Dammam</td>
<td>2288000</td>
<td>2353000</td>
<td>1601000</td>
<td>1294150</td>
<td>428267500</td>
</tr>
<tr>
<td>9</td>
<td>9.17</td>
<td>Al-Khober</td>
<td>238000</td>
<td>317000</td>
<td>246000</td>
<td>174350</td>
<td>65805000</td>
</tr>
<tr>
<td>10</td>
<td>10.16</td>
<td>Bqaiq</td>
<td>0</td>
<td>3000</td>
<td>3000</td>
<td>1650</td>
<td>10257020</td>
</tr>
<tr>
<td>11</td>
<td>11.9</td>
<td>Rmah</td>
<td>0</td>
<td>5000</td>
<td>0</td>
<td>1050</td>
<td>802500</td>
</tr>
<tr>
<td>12</td>
<td>11.16</td>
<td>AlAhsa</td>
<td>16000</td>
<td>161000</td>
<td>30000</td>
<td>88550</td>
<td>80250000</td>
</tr>
<tr>
<td>13</td>
<td>13.6</td>
<td>Hraimla</td>
<td>0</td>
<td>1016</td>
<td>0</td>
<td>460</td>
<td>535</td>
</tr>
<tr>
<td>14</td>
<td>14.7</td>
<td>Al-Deriah</td>
<td>0</td>
<td>360</td>
<td>0</td>
<td>187</td>
<td>535</td>
</tr>
<tr>
<td>15</td>
<td>14.8</td>
<td>Riyadh</td>
<td>1506000</td>
<td>3113000</td>
<td>1085000</td>
<td>653730</td>
<td>290237500</td>
</tr>
<tr>
<td>16</td>
<td>16.1</td>
<td>AlKhajir</td>
<td>1000</td>
<td>59000</td>
<td>0</td>
<td>12390</td>
<td>535</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>608109.4</td>
<td>601404.6</td>
<td>180093.3</td>
<td>630312.2</td>
<td>0000000827</td>
</tr>
</tbody>
</table>

Source: prepared by the researcher based on SCTA’s data 2007

| Table 4: Tourism destination characteristics data (target) in impact area
<table>
<thead>
<tr>
<th>Tourism destination (target) (j)</th>
<th>Variables data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (km2) (A)</td>
</tr>
<tr>
<td>Al-Dammam city</td>
<td>546, 51</td>
</tr>
<tr>
<td>Al-Dammam Corniche</td>
<td></td>
</tr>
<tr>
<td>Al-Khober district</td>
<td>864, 159</td>
</tr>
<tr>
<td>Al-Khober Corniche</td>
<td></td>
</tr>
<tr>
<td>Half-moon beach</td>
<td></td>
</tr>
<tr>
<td>Al-Aziziah</td>
<td></td>
</tr>
<tr>
<td>Al-Jubail district</td>
<td>007,26</td>
</tr>
<tr>
<td>Al-Jubail Industrial Corniche</td>
<td></td>
</tr>
<tr>
<td>Al-Jubail city Corniche</td>
<td></td>
</tr>
<tr>
<td>Al-Uqair center</td>
<td>345,509</td>
</tr>
</tbody>
</table>

Source: SCTA, 1430

* distance are illustrated in appendix 2
** proposed services in Al-Uqair tourism scheme, SCTA 1427
the natural components ($\tilde{v}_j$) represents the value (12, 1), and the tourism attractions ($\tilde{z}_j$) represents the value (66, 1). The positive variables coefficients indicate an increase along with the increasing variable. After obtaining the results of the coefficients calibration of variables, they will serve as modified weights.

It is clear from Table (6) and Table (7) that the fourth model is statistically adequate for prediction, based on the value of the increasing determination coefficient ($R^2 = 0.9665$) This indicates that the tourism demand in tourism destinations depends heavily on the variables given by the model. This is one of the methods used to evaluate the model. In addition, the significance level of the correlation coefficient reached zero (0.00), which is less than the significance level of hypothesis (0.05). Therefore, the regression line matches the data, which is within the limits used by geographers and others when accepting or rejecting the hypothesis that is usually in the limits of (0.50). So, after verifying the efficiency of statistical calibration, coefficients values will be used (adjusted weights) to forecast the tourism demand potential.

The results

Determining Al-Uqair tourism market share

Visual evaluation of the tourism impact area and tourism market share for tourism coastal destinations can be obtained by comparing the equivalence lines of tourism market in the destinations before and after adding Al-Uqair destination. Figure (8) shows tourism market influence lines to of Al-Dammam and Al-Khober together before adding Al-Uqair. There is a clear overlap in their influence lines, while Al-Jubail was not added because of its relative faraway distance from Al-Uqair.

Table 5: Partial list of multiple regression equation for set values

<table>
<thead>
<tr>
<th>Cell number</th>
<th>Tourism destination ($j$)</th>
<th>Dependent variables</th>
<th>Repelling tourism factors</th>
<th>Attracting tourism factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6</td>
<td>Al-Jubail</td>
<td>log($P_{ij}$ / $\bar{P}$) (Percentage/ geometric mean)</td>
<td>log($D_{ij}$ / $\bar{D}$) (Distance/ geometric mean)</td>
<td>log($V_{ij}$ / $\bar{V}$) (Area/ geometric mean)</td>
</tr>
<tr>
<td>1.6</td>
<td>Al-Dammam</td>
<td>-0.0863</td>
<td>-0.0631</td>
<td>-0.3619</td>
</tr>
<tr>
<td>1.6</td>
<td>Al-Khuber</td>
<td>0.01519</td>
<td>0.0410</td>
<td>0.4267</td>
</tr>
<tr>
<td>1.7</td>
<td>Al-Jubail</td>
<td>-0.01058</td>
<td>-0.0501</td>
<td>-0.3619</td>
</tr>
<tr>
<td>1.7</td>
<td>Al-Dammam</td>
<td>-0.00594</td>
<td>0.0180</td>
<td>-0.0648</td>
</tr>
<tr>
<td>1.7</td>
<td>Al-Khuber</td>
<td>0.1464</td>
<td>0.0446</td>
<td>0.4267</td>
</tr>
<tr>
<td>2.3</td>
<td>Al-Jubail</td>
<td>0.1652</td>
<td>0.0321</td>
<td>0.4267</td>
</tr>
<tr>
<td>2.3</td>
<td>Al-Dammam</td>
<td>0.0221</td>
<td>-0.0648</td>
<td>-0.0892</td>
</tr>
<tr>
<td>2.3</td>
<td>Al-Khuber</td>
<td>0.0410</td>
<td>0.0446</td>
<td>0.4267</td>
</tr>
</tbody>
</table>

Table 6: Results of multiple regression equation, model summary

<table>
<thead>
<tr>
<th>The model</th>
<th>Multiple link coefficient</th>
<th>Determination coefficient (RSquare a)</th>
<th>(Model Significance Level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.8311</td>
<td>0.6907</td>
<td>0.0000</td>
</tr>
<tr>
<td>2</td>
<td>0.8422</td>
<td>0.8397</td>
<td>0.0000</td>
</tr>
<tr>
<td>3</td>
<td>0.9216</td>
<td>0.9191</td>
<td>0.0000</td>
</tr>
<tr>
<td>4</td>
<td>0.9831</td>
<td>0.9665</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Dependent variable: log [Percentage/ geometric mean]
• Independent variable: log [Distance/ geometric mean]
• Independent variable: log [Distance/ geometric mean] and log [Area/ geometric mean]
• Independent variable: log [Distance/ geometric mean] and log [Area/ geometric mean] and log [Natural components/ geometric mean]
• Independent variable: log [Distance/ geometric mean] and log [Area/ geometric mean] and log [Natural components/ geometric mean] and log [Tourism attractions/ geometric mean]

Table 7: Forecasted coefficients ($a,b$)

<table>
<thead>
<tr>
<th>The model</th>
<th>Coefficients values $(B)$</th>
<th>Coefficients calibration error</th>
<th>Statistical significance level of Forecasted coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1,3379</td>
<td>0.0414</td>
<td>0.0000</td>
</tr>
<tr>
<td>2</td>
<td>-1,8636</td>
<td>0.0421</td>
<td>0.0000</td>
</tr>
<tr>
<td>3</td>
<td>1,1682</td>
<td>0.0301</td>
<td>0.0000</td>
</tr>
<tr>
<td>4</td>
<td>1,4023</td>
<td>0.0434</td>
<td>0.0000</td>
</tr>
<tr>
<td>5</td>
<td>1,8695</td>
<td>0.0325</td>
<td>0.0000</td>
</tr>
<tr>
<td>6</td>
<td>1,18100</td>
<td>0.0141</td>
<td>0.0000</td>
</tr>
<tr>
<td>7</td>
<td>1,1224</td>
<td>0.0442</td>
<td>0.0000</td>
</tr>
<tr>
<td>8</td>
<td>1,6622</td>
<td>0.0474</td>
<td>0.0000</td>
</tr>
</tbody>
</table>
existing tourist destinations within the tourism impact area. It is expected to distribute Al-Uqair market share between four tourism destinations after adding Al-Uqair instead of three tourism destinations. This can be identified through the application of the values of tourism demand potentials on the expenditure data for all source regions. The second column in the table clarifies the tourism market share before adding Al-Uqair. It is observed that the highest share of the current market belongs to Al-Dammam, followed by Al-Khober and then Al-Jubail. While the third column shows the potential tourism market after adding Al-Uqair. It was obtained using equation number (4.5). We note that all destinations have lost a part of tourists’ frequent visits. The forecasted loss of tourist destinations is approximately (-7.16%) from current tourists spending which will go to the new destination (Al-Uqair).

Table 8: Tourism market share of coastal tourism destinations before and after adding Al-Uqair

<table>
<thead>
<tr>
<th>Tourism destination (j)</th>
<th>Market share Before (%)</th>
<th>Market share After (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Dammam</td>
<td>62.02</td>
<td>59.66</td>
</tr>
<tr>
<td>Al-Khober</td>
<td>28.27</td>
<td>23.33</td>
</tr>
<tr>
<td>Al-Jubail</td>
<td>9.7</td>
<td>9.72</td>
</tr>
<tr>
<td>Proposed Al-Uqair</td>
<td>100.00</td>
<td>92.71</td>
</tr>
</tbody>
</table>

Table (8) indicates the quantitative estimation of the market share in the three existing tourist destinations within the tourism impact area. It is expected to distribute Al-Uqair market share between four tourism destinations after adding Al-Uqair instead of three tourism destinations. This can be identified through the application of the values of tourism demand potentials on the expenditure data for all source regions. The second column in the table clarifies the tourism market share before adding Al-Uqair. It is observed that the highest share of the current market belongs to Al-Dammam, followed by Al-Khober and then Al-Jubail. While the third column shows the potential tourism market after adding Al-Uqair. It was obtained using equation number (4.5). We note that all destinations have lost a part of tourists’ frequent visits. The forecasted loss of tourist destinations is approximately (-7.16%) from current tourists spending which will go to the new destination (Al-Uqair).

**Conclusion**

This study showed that the full potential of the Huff model has not been recognized yet. Adding to the Huff model in the business analyst program in (ArcGIS), the package is a positive step in this direction. There are many applications for this model not only in the field of tourism demand, but in other tourism aspects. For example, analyzing the tourism impact areas, assessing tourism market penetration, estimating the tourism development impact, assessing the tourism environmental impacts, predicting tourist preferences, and finally describing the tourists’ distribution patterns geographically. The study recommended the possibility of circulating the application of the model to tourist destinations similar to Al-Uqair in various regions of the Kingdom. The results of the Huff model coefficients calibration are applicable to several tourist destinations without making any changes. Running the proposed model’s progress scheme is fast and practical and saves a lot of effort and money, only in case of compliance with the terms and objectives of the model in addition to the required level of details.

**References**

**Arabic references**


**Foreign references**


The paper was presented at the Eighth National GIS Symposium in Saudi Arabia during 15 – 17 April 2013.

Figure (9) shows the influence lines of the tourism market in the existing tourist destinations after adding Al-Uqair. The differences in the distribution pattern of the lines after adding Al-Uqair is clear. It may be difficult to assess the impact visually, due to the large and overlapping equivalent lines. Al-Uqair share of the current tourism market can be determined.

Table 8 indicates the quantitative estimation of the market share in the three

Figure 8: Equivalence lines of tourism market influence around Al-Dammam and Al-Khober before adding Al-Uqair

Figure 9: Equivalence lines of tourism market influence around Al-Dammam and Al-Khober after adding Al-Uqair
Because it’s easy to use, provides the clearest results, and offers the most flexibility of any least squares program. While some surveyors may be confident in the solutions produced by their instrumentation, a true professional surveyor considers it critical that they apply a least squares adjustment to every survey. Download a free demo from our website: www.microsurvey.com
It’s not every day that a musician inspires a mapmaker.

But that’s what happened at the 2013 Esri International User Conference (Esri UC) in San Diego, California. It’s where will.i.am, the recording artist and founder of the Black Eyed Peas, helped Katherine O’Brien, GIS coordinator for facilities at the University of North Carolina (UNC), Chapel Hill, make the decision to start mentoring students in how to use geospatial technology.

“I need to go back and work with kids,” said O’Brien, who credited will.i.am for inspiring her to get involved.

will.i.am, born William James Adams, started the i.am.angel Foundation in part to support science, technology, engineering, and mathematics (STEM) education in the classroom. He spoke for 30 minutes with Esri president Jack Dangermond about his passion for helping young people get a strong STEM education, including learning to use GIS.

Prior to their conversation, four 11th-graders from Roosevelt High School in the Boyle Heights neighborhood of Los Angeles, California, demonstrated how they used GIS to analyze data using Esri’s mapping software. will.i.am, who grew up in Boyle Heights, arranged for them to use ArcGIS for their school projects.

“It’s important to be tech savvy and computer literate today, said will.i.am. “Most people don’t read or write code, but we all use technology to communicate,” he said. See the rest of the conversation at esri.com/events/user-conference.

Transforming India

Esri UC keynote speaker Sam Pitroda, an adviser to India’s prime minister on public information, infrastructure, and innovations, outlined India’s plan to build a national GIS as part of a public information infrastructure. He said 400 million people live below the poverty line in the country of 1.3 billion and that democratizing information using technology help lift them out of poverty.

Sam Pitroda believes GIS will be critical to turning India into an information-rich society.

The creation of a nationwide GIS platform has begun, with plans to use the technology to tag every physical asset in the country and unique identifications (UIDs) for all residents. GIS would help streamline everything from the justice system to the food distribution system and improve housing and education, Pitroda said. “Our goal is really to empower a billion people with knowledge information, and this is where GIS, we believe, will play an important role,” he said.

Transforming Urban Areas

The new Urban Observatory opened at the Esri UC. It uses Esri technology to compare demographic and other information about major cities at the same scale.
With over 250 attendees from 40 countries, the RIEGL LIDAR 2013 International Airborne, Mobile, Terrestrial & Industrial User Conference turned out to be the LIDAR event of the year. The conference took place at the Vienna Marriott, right in the magnificent historic city center of Vienna. Program highlights included presentations of the latest hardware and software by RIEGL and more than 80 User-, Partner-, and Scientific presentations by international leading LIDAR experts in various tracks. Special Sessions included presentations on bathymetry, architecture, geology, and UAV applications, to name just a few. Moreover, 20 industry leading companies including Gold Sponsors Applanix, ESRI and Trimble exhibited and gave a partner presentation.

To kick off the conference, the new RIEGL LMS-Q1560, which represents the future of airborne laser scanning technology, was unveiled to the international audience. Only one day after the official unveiling, RIEGL gladly announced the first LMS-Q1560 sale to a long-standing customer in Canada. RIEGL also presented several other exciting hardware and software news:

• the VMX-450-RAIL: high end mobile mapping system optimized for usage on railways
• RISOLVE, RIEGL’s new software package designed for use with the VZ-400 and VZ-1000 terrestrial laser scanners for collision investigation and scene reconstruction, simplifying the acquisition process and reducing processing time dramatically
• RIPRECISION, RIEGL’s new software package created for use with the RIEGL family of mobile scanning systems. The powerful software adjusts overlapping data to create a very precise point cloud for the end user.
• Right in time for the conference, technology startup rapidlasso has released an open data exchange format called “PulseWaves” for storing full waveform LiDAR data.

In addition to the conference itself, technical workshops were provided, a tour of the RIEGL headquarters in Horn was given and a technical excursion to RIEGL’s airborne partners Airborne Technologies, Diamond Airborne Sensing and Schiebel in Wiener Neustadt south of Vienna was made.

The Highlight of the social program was Wednesday evening’s Gala Dinner. The RIEGL community came together in a spectacular, ultra-modern ambience for high class entertainment in the heart of Vienna, and spent a wonderful evening together.
National cartography of Peru to be digitized

The National Geographic Institute (IGN), the mapping agency of Peru, has launched a project for digitisation of national cartography. The idea of the project is to have a high precision data in order to contribute to the growth of public and private investments that can benefit from this updated mapping information. The institute is looking at generating a basic cartography scale 1/25,000 of Moquegua and Tacna Departments. www.ign.gob.pe/...

Geo data online in a German State

Mecklenburg-Vorpommern, a federal state in north Germany is planning to implement “Municipal Geo-information System” in all its municipalities. The aim is to create an online portal to provide geodata collected through local government’s GIS system. Currently, the local government has data on land-use plans, road cadastre, land registry tree etc. It can be seen with reference to population and economic indicators. Once the data is put online, it will open up the possibility of meeting the INSPIRE Directive and EU regulations for spatial information in the European Union.

Indonesia promotes use of GIS for economic development

The Ministry for Development of Disadvantaged Regions is working together with the Geospatial Information Agency (formerly known as BAKOSURTANAL); Indonesia to support the development of several key sectors and industries in some of the country’s most disadvantaged areas. The agency will be providing its expertise to promote the use of geospatial information to pump prime sectors such as agriculture, mining, energy, marine, tourism and telecommunications. www.futuregov.asia

Mapping a healthy future for SA children

With nearly a quarter of South Australian children overweight or obese, SA Health, in partnership with the state’s local governments tackling the issue by developing community awareness and education policies, programs partnerships and infrastructure. Key to this strategy is the Obesity Prevention and Lifestyle (OPAL) program, which supports children’s health through educating their families and communities. Part of the OPAL program is an eight year evaluation which uses GIS technology to monitor and analyse existing infrastructure, environments and resources – such as playgrounds and recreation facilities – to better target state and local governments’ policy and intervention efforts. http://esriaustralia.com.au

Poland to implement Geoportal 2

The Head Office of Geodesy and Cartography of Poland is getting ready to implement Geoportal 2. The main goal of the project is to provide citizens, businesses and public administration access to government registers, which contain high quality, current and reliable data. As a result of the project, services related to spatial data will also be enabled.

Atlas Qatar ranked first at Esri UC

Atlas Qatar and its digital publication were ranked first in the world during the International Conference of GIS, organized by the Esri in San Diego, USA. The Ministry of Development Planning & Statistics (MDPS) participated in this conference with its up-to-date publications, Atlas Qatar and Digital Atlas, which were developed and drafted using the latest techniques of GIS. www.gulf-times.com

Ghana is developing national spatial planning framework

Ghana is developing a National Spatial Development Framework to guide the provision of amenities and facilities in the various districts and regions in the country, said Mr Richard Geier, Manager of the Framework Programme, recently. He said the framework would facilitate a balanced redistribution of urban population, adding that, “it would enable development planners to know which districts are under-served and those that are over-served in terms of the development of infrastructure and distribution of amenities”. He called for the enactment of legislation on land use spatial planning, to strengthen the legal framework for land use. www.ghanaweb.com

Johor to map out rural roads digitally

Johor will be the first state in Malaysia to map out over 5,000 kilometres of its rural road network digitally to update and improve their management. The project will be carried out by Infra Desa Johor Sdn Bhd (IDJSB), a state-owned company that is responsible for the maintenance of these roads, and Universiti Teknologi Malaysia (UTM). IDJSB shall use the expertise of the lecturers and students of UTM’s Faculty of Geoinformation and Real Estate. www.nst.com.my

First GPU-Accelerated Platform for Geospatial Int Analysts launched

NVIDIA has launched the NVIDIA® GeoInt Accelerator™ to enable security analysts to find actionable insights quicker and more accurately than ever before from vast quantities of raw data, images and video. It provides defense and homeland security analysts with tools that enable faster processing of high-resolution satellite imagery, facial recognition in surveillance video, combat mission planning using GIS data, and object recognition in video collected by drones. www.nvidia.com

Federal Security Geospatial Portal launched in UAE

Major General Ahmed Nasser Al Raisi, Director General of Central Operations, launched the first edition of the Federal Security Geospatial Portal, the first-of-its-kind in the region in terms of its institutional characteristics and its comprehensiveness of implementation. The portal includes tens of police and digital maps that are designed and developed internally through idea exchange and efforts made by international experts in the fields of GIS. The portal’s aim is to serve over 18 security and police entities, and police stations at the UAE level. ▶
Falcon 9 rocket to deliver RADARSAT Constellation to Orbit

Space Exploration Technologies was awarded a launch reservation contract with MacDonald, Dettwiler and Associates Ltd. (MDA) to support the largest space program to date in Canada, carrying the three satellites to orbit that will make up the RADARSAT Constellation Mission (RCM) on a Falcon 9 rocket in 2018. RCM is a three satellite configuration and will support Canada’s need for maritime surveillance, disaster management and ecosystem monitoring. www.spacex.com

Pakistan approves Remote Sensing programme

The Executive Committee of the National Economic Council, Pakistan approved the project of Pakistan Remote Sensing Satellite (PRSS) located in Sindh and Punjab with cost of Rs.19695.0 million. The project is part of National Satellite Development Programme for space technology and its application will be in Pakistan, institutional capacity building of SUPARCO and relevant organizations. www.app.com.pk

First national carbon map using satellite imagery, LiDAR

Researchers have mapped the above ground carbon density throughout the Republic Panama in high resolution. This is the first time when such mapping has been done for an entire country. Researchers integrated field data with satellite imagery and high-resolution airborne Light Detection and Ranging (LiDAR) data to map the vegetation and to quantify carbon stocks.

Researchers from Smithsonian Tropical Research Institute (STRI), McGill University and UC-Berkeley found Panama to be an ideal laboratory to develop and test a method for quantifying aboveground carbon because of its complex landscapes, with variable topography, and diverse ecosystems. They combined ground-based plot sampling, satellite imagery, and LiDAR measurements from the Carnegie Airborne Observatory to carry out the project. The new system, described in Carbon Balance and Management, will greatly boost conservation and efforts to mitigate climate change through carbon sequestration. http://cao.ciw.edu/

Satellite imagery has revealed that Saudi Arabia is targeting Israel and Iran

Saudi Arabia doesn’t have formal ties with Israel and treats Iran as enemy too. The satellite pictures show a previously undisclosed surface-to-surface missile base in the middle of the Saudi desert, the Telegraph reported. Analysts say they saw in the images at least two launch pads — one pointing toward Tel Aviv and another toward Tehran. www.washingtonpost.com

UAE contract to Astrosat and Thales

The United Arab Emirates Armed Forces on July 22 contracted with Astrosat Satellites and Thales Alenia Space of France to provide the two-satellite Falcon Eye high-resolution optical reconnaissance system.

It includes the construction of two satellites weighing less than 1,500 kilograms each; their separate launches in late 2017 and early 2018.

Industry officials said that they would use the same satellite platform as the French government’s two Pleiades satellites, which operate in 700-kilometer polar low Earth orbits.

Thales Alenia Space will be providing the Falcon Eye imaging payload, with Astrosat Satellites building the platform. Both companies said their hardware would be upgraded versions of what they built for Pleiades.

The contract was signed in Abu Dhabi during a ceremony presided over by Sheikh Mohammed Bin Zayed Al Nahyan, the UAE crown prince, who is also head of the UAE armed forces; and by Jean-Yves Le Drian, the French defense minister. www.spacenews.com

How Mercedes-Benz R&D is using Google Glass

Mercedes-Benz Research & Development North America (MBRDNA) is working on a way to take advantage of the Google’s newest GPS-equipped device: Google Glass. According to MBRDNA President and CEO Johann Jungwirth, the company's ultimate goal on the Google Glass project is a “seamless” door-to-door transition between pedestrian directions and in-car GPS. www.bizjournals.com

Castrol partners with TomTom

Castrol has partnered with TomTom to study the impact of “stop-start” driving patterns across the world. The study already shows that drivers can experience as many as 18,000 stop-starts every year. The pioneering study that Castrol is undertaking with TomTom will discover the number of stop-starts in different cities around the world, and TomTom will use its precise travel and traffic information to analyse driving behaviour across the entire road network, all over the world. http://corporate.tomtom.com

Location, usage patterns to save iPhone battery life

The U.S. Patent and Trademark Office has published an Apple patent application for an intuitive mobile device control system that automatically powers down certain components.

In its aptly named application, “Power management for electronic devices,” Apple describes a system that detects a mobile device owner’s usage patterns, estimates the required energy needed to run the phone between charges, and dynamically turns hardware off or closes running software to achieve maximum battery life. http://appleinsider.com

Pedestrian navigation solution in real-world setting by Movea

Movea has collaborated with the SNCF, France’s national railway company, as well as SK planet, a wholly owned subsidiary of SK telecom, South Korea’s largest
Encouraging Galileo GNSS and EGNOS Use in the Mediterranean Basin

A European-Union funded consortium invites companies and public agencies from North Africa and the Middle East to submit ideas for extending Galileo GNSS and EGNOS use in the region. Eligible ideas could be for a small pilot project or research study, a technical training plan, and/or a publication or article. The submission deadline is August 25, 2013.

The countries in the target area are Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, Syria, and Tunisia. www.euromedtrasport.eu

European Space Agency – Ground Station Endures Freak Weather

Engineers manning Galileo’s South Pacific ground station on New Caledonia found themselves marooned by heavy rains and a flash flood—though the station carried on operating regardless. Torrential rains lashed this French-administered group of islands at the start of July. The Galileo ground station near the capital Nouméa was caught in the deluge. Part of a growing worldwide network, it incorporates a Galileo Sensor Station that monitors the quality of navigation signals and an Uplink Station to relay navigation corrections to the satellites for rebroadcast to users. www.satnews.com

Britain Now Sees Potential of PRS Signal aboard Galileo

The British government’s skepticism about the value of the encrypted, jam-resistant signal on Galileo satellite constellation has given way to an embrace of the signal as a future revenue source for British industry, government and industry officials said.

The Public Regulated Service (PRS) signal onboard Galileo will be available to European Union (EU) governments that provide security guarantees to specially designated Galileo program managers. Several European governments have said they plan to equip their emergency response teams and civil security forces. Several, notably France, have said they intend to supply their militaries with PRS-equipped hardware even as they maintain their use of the future military, or M-code, signal on the U.S. GPS satellites.

The British government in the past has openly questioned PRS’s value, and even suggested that it has no place as a military component in a project that is financed and managed by civilian authorities. Some of this opposition was concerned that anyone expressing interest in PRS would be forced to pay for it. This led several European defense ministries to soft-pedal their support for it. That has now changed. www.spacenews.com

Galileo GNSS service centre opened in Spain

The European GNSS Service Centre (GSC) was opened this month in Torrejón de Ardoz, Madrid, Spain, and will give information on the status of the Galileo constellation to application service providers and other users. This will help companies and organisations that are reliant on the constellation to ensure they can maintain the provision of any relevant products or services.

Predict your location years into the future

A new piece of software claims to be able to predict your location years into the future – even if you don’t know where you’ll be. ‘Far Out’ is the result of statistical research that looks at GPS data, learns your typical movements and then extrapolates to decide on your likely future location. The result, according to the team behind it, systems that can make “highly accurate” predictions about where you’ll be years down the line. www.huffingtonpost.co.uk

Esri and MapmyIndia business alliance

Esri has announced a strategic alliance with MapmyIndia. MapmyIndia will migrate its data production environment to the ArcGIS platform, allowing it to leverage Esri’s high-end cartographic production tools and workflows to expand its range of products. The alliance will provide Indian application developers and end users with a high-performance, cost-effective platform for GIS and location-based services development. In addition Esri’s cloud-based ArcGIS Online will help democratize GIS data access throughout India with its low-cost subscription plans. www.mapmyindia.com

Ruckus buys YFind, navigates its way into indoor-positioning market

Wi-Fi services provider Ruckus Wireless acquired privately held indoor-positioning company YFind Technologies. Ruckus said it intends to use YFind’s location-based services (LBS) and analytical capabilities in combination with Ruckus’ Smart Wi-Fi technology, “transforming Ruckus Smart Wi-Fi networks into location-intelligent infrastructures.”
US critical infrastructure sectors at risk from GPS


IRNSS-1A, India’s First Navigation Satellite successfully launched

ISRO’s Polar Satellite Launch Vehicle, PSLV-C22, successfully launched IRNSS-1A, the first satellite in the Indian Regional Navigation Satellite System (IRNSS) on July 2, 2013 from Satish Dhawan Space Centre, Sriharikota, India. After a flight of 20 minutes 17 seconds, the IRNSS-1A Satellite, weighing 1425 kg, was injected to the intended elliptical orbit of 282.46 km X 20,625.37 km.

After injection, the solar panels of IRNSS-1A were deployed automatically. ISRO’s Master Control Facility (at Hassan, Karnataka) assumed the control of the satellite. All Navigation and Ranging Payload In Orbit Tests (IOT) are completed and all operations are normal. www.isro.gov.in

Russia to launch two GLONASS satellites after Proton disaster

“We are planning to launch two satellites from the Plesetsk space center [in northern Russia] to replenish the GLONASS orbital grouping following the recent Proton-M accident,” said Nikolai Testoyedov, the head of the Information Satellite Systems (ISS) company, which manufactures satellites for the GLONASS project. The first GLONASS is scheduled for launch in the beginning of September, and the second at the end of October, according to Testoyedov.

Russia loses $200 million satellites

Russian rocket carrying three navigation satellites worth around $200 million crashed shortly after lift-off from the Russian-leased Baikonur launch facility in Kazakhstan after its engines suddenly switched off.

Foreign airlines urged to use GPS at San Francisco

Federal aviation officials in US have advised all foreign airlines to use a GPS

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For more information:
system instead of visual reckoning and cockpit instruments when landing at San Francisco International Airport in the wake of the deadly Asiana Airlines crash.

The FAA issued the recommendation involving main runways at the airport, saying in a statement that it took the action after noticing an increase in aborted landings at the airport by some foreign carriers flying visual approaches into the airport. http://abcnews.go.com

GPS flaw could let terrorists hijack ships, planes
Captain Andrew Schofield and Todd Humphreys, a GPS expert at the University of Texas, used a GPS flaw to take control of the sophisticated navigation system aboard an $80 million, 210-foot super-yacht in the Mediterranean Sea. The world’s GPS system is vulnerable to hackers or terrorists who could use it to hijack ships -- even commercial airliners, according to a frightening new study that exposes a huge potential hole in national security.

Using a laptop, a small antenna and an electronic GPS “spoofer” built for $3,000, GPS expert Todd Humphreys and his team at the University of Texas took control of the sophisticated navigation system aboard an $80 million, 210-foot super-yacht in the Mediterranean Sea. www.foxnews.com

Precise GPS measurement finds 117 km difference in Indo-Nepal border
Precise measurement using GPS has found that Indo-Nepal border is 117 km longer than previously believed. The latest survey has estimated the Indo-Nepal border was closer to 1,868 km, 117 km more than the official length of 1,751 km. An official emphasized it was technology – and not a change in the location of border pillars that stretched the Indo-Nepal borders. Previously, surveyors used to walk along the border with metal chains measuring short lengths and then adding them up. This time the surveyors used GPS to measure angles and distances. www.hindustantimes.com

AAI starts training staff on GPS-based navigation system
Moving a step closer towards implementation of satellite-based navigation system, the Airports Authority of India (AAI) has started training its staff to familiarize them with GPS-Aided Geo Augmented Navigation system (GAGAN). AAI had organised a three-day workshop-cum-training session for about 40 senior, instructor level, officials at the Civil Aviation Training College at Allahabad. www.thehindubusinessline.com

GPS for safety of houseboats in Kerala, India
A GPS-based fleet safety management system will be introduced for houseboats, the mascot of Kerala Tourism. The system will track houseboats and ensure the safety and security of tourists while they cruise the backwaters.

Besides tracking and locating houseboats on a GIS map and timely emergency response, the route travelled by a houseboat can also be “geofenced” to receive alerts on any route violations. www.thehindu.com

Lawmakers oppose Roscosmos funding reduction and GLONASS system scrapping
Members of the State Duma demand from the government to prevent reduction of Roscosmos programs funding, since it may lead to a scrap to GLONASS system functioning and Vostochny booster side building.

According to the minutes of the Duma Committee on Industry, adopted after the meeting with Roscosmos head Vladimir Popovkin, the proposal is to reduce budget funding of the state space program of Russia in 2014 for 11.7 billion rubles, in 2015 - for 13.5 billion rubles and for 40 billion rubles in 2016. In addition to this, the federal space program of Russia for 2006-2015 /FSP-2015/ already lacks of 10.5 billion rubles funding, and this year there has been a 2.3 billion rubles additional reduction in R&D under this program. http://indras.in

AG-STAR GNSS antenna is cost-effective L1 GPS+GLONASS receiver plus antenna system is housed in a single, low profile, rugged enclosure. It is ideal for manual guidance and auto steer installations. Its design interface maximizes flexibility with two NMEA 0183 compatible RS-232 serial ports and a NMEA2000 compatible CAN port. One PPS output, an event mark input and three daylight readable status LEDs are also provided.

The SMART6 antenna integrates NovAtel’s powerful OEM6™ GNSS receiver engine with its high performance Pinwheel™ antenna technology. Tracking L1 and L2 GPS + GLONASS signals, and E1 Galileo and BeiDou B1 ready, it delivers scalable performance, from single-frequency positioning to centimetre-level accuracy using dual-frequency RTK tracking.

OEM638™ GNSS receiver card and the ProPak6™ enclosure
NovAtel has added OEM638™ GNSS receiver card and the ProPak6™ enclosure to its OEM6 family of high precision positioning products. The most advanced card within NovAtel’s OEM6 GNSS receiver family, the OEM638 tracks all existing and planned constellations including GPS, Beidou, GLONASS, Galileo and QZSS.

The ProPak6 is NovAtel’s most sophisticated GNSS enclosure product, offering metre-level to centimetre-level positioning in an extremely rugged, water resistant IP67 housing. Standardized software and hardware connections, including multiple RS-232/RS-422 serial ports, CAN Bus, USB host and device, as well as Bluetooth®, Wi-Fi and optional cellular radio, speeds time to market and maximizes user capabilities.
ZTS Series
Total Station

ZTS-120/120R

- Intelligent Calibration, USB Port&Bluetooth Optional
- Reflectorless Distance Measurement, Range Up To 350M
- Integrated Optical, Mechanical and Electrical Precision Ranging System, Accuracy: 2mm±2ppm
- High Efficient Absolute Encoder Angle Measuring System, Accuracy: 2"

Simply Powerful

Hi-Target Surveying Instrument Co., Ltd
www.hi-target.com.cn
www.gnss-gps.com
ADD: 10th Floor, Chuanxiong Building, Tianhe Technology Zone, No. 555, North of Panyu Road, Panyu District, 511400, Guangzhou City, China
Tel: +86-20-22883930
Fax: +86-20-22883980
E-mail: info@zhtgps.com
Schwarz is a GNSS simulator aimed at vector signal generator from Rohde & Schwarz. A new option on the SMBV100A vector signal generator simulated satellite system to Rohde & Schwarz adds online publication store. It is available from RTCM at its secure (MSM) format. The amended standard in the new Multiple Signal Message (MSM) format. The amended standard introduces an ephemeris amendment to RTCM 10403.2, the widely-used “Version 3” standard for Differential Global Navigation Satellite System Services (DGNSS). RTCM’s standard supports very high accuracy navigation and positioning through a broadcast from a reference station high accuracy navigation and positioning (DGNSS). RTCM’s standard supports very high accuracy navigation and positioning through a broadcast from a reference station to mobile receivers. Looking forward to the use of new satellite positioning systems from Europe and China, the amendment introduces an ephemeris message for the Galileo Open Service (E/NAV), and also a set of BeiDou messages in the new Multiple Signal Message (MSM) format. The amended standard is available from RTCM at its secure online publication store.

Rohde & Schwarz adds simulated satellite system to vector signal generator

A new option on the SMBV100A vector signal generator from Rohde & Schwarz is a GNSS simulator aimed at developers of satellite-based navigation instruments. The new SMBV-K101 option allows developers to test GNSS receivers for specific effects such as obscuration and multipath propagation. Buildings, tunnels and bridges as well as reflections from concrete and glass surfaces affect the GNSS signal, regardless of whether the receiver is stationary or in motion, and this option makes it easy to configure these kinds of scenarios.

If the GNSS receiver of a navigation instrument or smartphone is located inside a vehicle, testing must also take into account the obscuring effect of the vehicle’s metal body. The R&S SMBV-K102 option can simulate this obscuration and, if required, also the additional antenna pattern.

Premium services for ArcGIS Online Users by DigitalGlobe and Esri

Esri ArcGIS Online users will now have access to DigitalGlobe’s Premium Services. The new offering brings expanded geospatial products and solutions to select users of ArcGIS Online on a subscription basis. With this exciting partnership, DigitalGlobe’s Global Basemap, FirstLook, and Multispectral Premium Services can now be seamlessly integrated into the workflow of ArcGIS users, allowing them to access the most current imagery and information available directly from the source! www.digitalglobe.com

New Inertial system to SBG Systems, Ekinox Series

With integrated Dual Antenna GPS + GLONASS receiver, the Ekinox-D is a ready-to-use Survey Grade inertial navigation system which provides consistent true heading (0.05°). It is a high performance inertial navigation system which embeds a Dual Antenna L1/L2 GNSS receiver to deliver more robust heading and position, while increasing satellite reception availability. GNSS data and inertial information are fused by an Extended Kalman Filter (EKF) to improve data integrity.

FARO Technologies, Inc. has announced the new FARO CAM2 SmartInspect measurement software. The new software is highly suited to take measurements without CAD data. In developing the software, the focus was on - Simple, Intuitive operation and A Short learning phase. This means that even users with minimal background knowledge of 3D measurement technology can achieve very good measuring results within a short period of time. www.faroasia.com

Lockheed Martin GPS III Satellite prototype

Lockheed Martin recently delivered a full-sized, functional prototype of the next-generation GPS satellite to Cape Canaveral Air Force Station to test facilities and pre-launch processes in advance of the arrival of the first GPS III flight satellite.

The GPS III Non-Flight Satellite Testbed (GNST) arrived at the Cape on July 19 to begin to dry run launch base space vehicle processing activities and other testing that future flight GPS III satellites will undergo. www.lockheedmartin.com/gps

Field-ready RF recorder captures wideband multi-GNSS signals

AVERNA RP-5300 RF Recorder is specifically adapted for all GNSS applications, including Galileo, GPS, GLONASS, and Compass. System has two 50-MHz wide channels that can be tuned on any frequencies from 330 MHz to 2500 MHz. http://www.averna.com

Cm level accuracy for Mobile GIS Applications by Septentrio

Septentrio has joined forces with Esri to offer a user friendly mobile solution that is accurate up to 1 centimeter. This mobile solution combines the use of Esri ArcGIS for Mobile with a highly accurate GNSS device called AsteRx-m™ GeoPod. The combination of Esri software and the AsteRx-m™ GeoPod
Maximize Your Uptime

StarFire Rapid Recovery Keeps You Going

Worksite conditions are seldom perfect and GNSS signal outages can cause costly delays, but NavCom will help get you up and running again with StarFire Rapid Recovery.

NavCom’s new StarFire Rapid Recovery feature helps you bridge GNSS signal interruptions by allowing you to quickly regain StarFire accuracy up to 5cm once the GNSS signal is reacquired. NavCom’s StarFire Network, a Global Satellite Based Augmentation System, provides five centimeter horizontal accuracy worldwide. It offers 99.999% uptime, a seven satellite constellation, and StarFire over IP (SFiP) delivery for redundancy to ensure system availability and position accuracy.

We understand that in order to do the job right, you need the right tools and NavCom’s suite of StarFire productivity tools including StarFire Rapid Recover, StarFire Over IP delivery and RTK Extend help users reduce costs, and maintain maximum uptime.
New TruPulse Laser rangefinders by Laser Technology

Laser Technology, Inc. has released two new TruPulse laser rangefinders, the 200X and 200L. Both measure slope distances and degree of inclination allowing the unit to calculate horizontal and vertical distances, height and 2D missing line values. The new TruPulse 200L is designed for the cost-conscious professional while the new TruPulse 200X caters to those who require a much higher degree of accuracy and overall durability.

Integrated GIS, Mapping receiver by Topcon

Topcon Positioning Systems (TPS), HiPer SR for GIS is a compact, integrated GNSS receiver with sub-meter accuracy. Additional, scalable options are available via OAF (Options Authorization File) upgrades, delivering accuracy levels of sub-decimeter and centimeter without the need for additional hardware. It can be paired with a Topcon controller and eGIS software, or used with Topcon’s eGPS utility software to use with a third-party device and application.

www.topconpositioning.com

Intel to acquire ST-Ericsson GNSS portfolio

Assuming that its deal to acquire ST-Ericsson’s GNSS business closes soon, Intel Corporation will find itself with expanded opportunities – and competitive set – in the mobile location marketplace.

ST-Ericsson’s G1960 chip, built with 40-nanometer CMOS technology, provides GPS, GLONASS, Quasi-Zenith Satellite System (Japan’s QZSS), satellite-based augmentation system (SBAS), and assisted-GNSS functionality. A nascent BeiDou capability is reportedly also in the connectivity unit’s technology mix.

MARK YOUR CALENDAR

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<tr>
<th>September 2013</th>
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<tr>
<td>JISDM 2013</td>
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<tr>
<td>The University of Nottingham, UK</td>
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<td><a href="http://www.nottingham.ac.uk/engineering/conference/jisdm/index.aspx">www.nottingham.ac.uk/engineering/conference/jisdm/index.aspx</a></td>
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<tr>
<td>Multi-GNSS environment for sustainable development</td>
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<tr>
<td>Hoi An, Vietnam</td>
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<td><a href="http://navis.hust.edu.vn">http://navis.hust.edu.vn</a></td>
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<tr>
<td>Geo-Empower Middle East Summit</td>
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<td>Dubai, UAE</td>
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<td><a href="http://www.fleminggulf.com/All-Categories">www.fleminggulf.com/All-Categories</a></td>
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<tr>
<td>ION GNSS 2013</td>
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<tr>
<td>Nashville, Tennessee, USA</td>
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<td><a href="http://www.ion.org">www.ion.org</a></td>
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<td>GDI APAC 2013: Geospatial Defence &amp; Intelligence 2013</td>
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<tr>
<td>Singapore</td>
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<td><a href="http://www.geospatialdefenceasia.com">www.geospatialdefenceasia.com</a></td>
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<tr>
<th>October 2013</th>
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<tr>
<td>Intergeo 2013</td>
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<tr>
<td>Essen, Germany</td>
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<td>UN-GGIM 16-18 October</td>
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<td>34th Asian Conference on Remote Sensing</td>
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<td>Bali, Indonesia</td>
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<td>ISGNSS 2013</td>
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<th>November 2013</th>
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<tr>
<td>GSDI World Conference (GSDI14) and the AfricaGIS 2013 Conference</td>
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<tr>
<td>Addis Ababa, Ethiopia</td>
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<td><a href="http://www.gdsi.org/gsdi14/">www.gdsi.org/gsdi14/</a></td>
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<td>ICG-8: Eighth Meeting of the International Committee on GNSS</td>
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<td>Dubai, United Arab Emirates</td>
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<td>SPAR Europe/European Lidar Mapping Forum</td>
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<td>Amsterdam, The Netherlands</td>
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<td><a href="http://www.sparpointgroup.com/Europe/">www.sparpointgroup.com/Europe/</a></td>
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<tr>
<td>ISPRS: Serving Society with Geoinformatics</td>
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<tr>
<td>Antalya, Turkey</td>
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<td><a href="http://www.isprs2013-ssg.org">www.isprs2013-ssg.org</a></td>
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<th>December 2013</th>
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<tr>
<td>ION Precise Time and Time Interval Meeting (PTTI)</td>
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<tr>
<td>Bellevue, WA, United States</td>
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<td><a href="http://www.ion.org">www.ion.org</a></td>
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<td>Fourth ESA Colloquium on Galileo</td>
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<td>Prague, Czech Republic</td>
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<td><a href="http://www.congressprojects.com/13c15/">www.congressprojects.com/13c15/</a></td>
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<tr>
<td>6th European Workshop on GNSS Signals and Signals Processing</td>
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<td>Munich, Germany</td>
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<th>January 2014</th>
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<tr>
<td>ION International Technical Meeting</td>
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<td>San Diego, California, USA</td>
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<tr>
<td>Munich Satellite Navigation Summit 2014</td>
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<td>Munich, Germany</td>
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<td><a href="http://www.munich-satellite-navigation-summit.org">www.munich-satellite-navigation-summit.org</a></td>
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<th>April 2014</th>
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<tr>
<td>ENC-GNSS 2014</td>
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<td>Rotterdam, The Netherlands</td>
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<th>June 2014</th>
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<tr>
<td>XXV FIG Congress</td>
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<td>Kuala Lumpur, Malaysia</td>
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<td><a href="http://www.fig.net">www.fig.net</a></td>
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S320™

GNSS Survey Receiver Solution

Built Surveyor
Tough

Includes:

Xi²™ Data Collector
Carlson SurvCE Data Collection Software

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