DIGITAL MAPPING:
COST EFFECTIVE CAPTURING MAKES GIS DATA FOR COUNTRIES AND CITIES MORE ACCESABLE

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Executive Summary

Georigin have formulated a bulk digital mapping methodology to accurately and effectively map virtually any country or city in the world, by combining and analyzing affordable and existing data sources, and maintaining the data in a unique way. Our capabilities, products and services are all related to map data for digital & paper publication and GPS based applications. We offer off-the-shelf GIS data for countries and cities as well as a service to capture data in virgin territory.

Starting with African countries and cities as Phase 1 – the capturing process has been refined and tested in such a way that it can be used for Military and Commercial purposes. Affordable High- and Medium resolution satellite imagery, combined with the SRTM data, GPS data and Field Information obtained from our own field teams and a network of local partners, presented us with a way to capture and maintain the spatial data for these countries.

Introduction

A lot of mapping and mapping related organizations still lack the skills, technology and data to properly construct GIS data for mapping related purposes. This is especially true for the countries in the developing parts of the world. These countries would typically include most of Africa, sections of the Middle East and Asia, parts of South America and Indonesia. This is also applicable to a large proportion of the Eastern Block countries that were previously mapped by the Russian Federation, but have not been maintained or updated in GIS Vector formats. Although the developed world does have access to the best available technology and data, we believe that our approach to bulk GIS data capture is unique, and can be implemented at a much larger scale.

What are the primary sources of data?

Our primary sources of data for building a country or city in GIS format are the following:

- Existing Topographic maps – at the best scale available for seamless coverage of each country – are always the first step in mapping a country. There are a number of commercial providers for Topographic maps and a quick search on the Internet can lead you to a few of them. Should you not be able to get the Topographic maps from the National or Commercial providers, then look at the Russian declassified Topographic maps – available for most countries in the World.
- SRTM – The 90m SRTM data is of extreme importance once you start mapping rivers and catchment areas. The 90m SRTM data can be obtained free of charge from the USGS.
- Eartsat 2000 Stock Scenes of the World. (The Cubic Convolution option of the raw Landsat TM 7 imagery)
- Quickbird, Ikonos or Spot 5 imagery
- Aster 30m DEM (SRTM 30m when available)
- GPS Ground Control Points or GPS drive Tracks
- Web mapping community

How are the data sources utilized for Feature Extraction?

There are 2 different methodologies used for the capturing of a country based dataset and a city or town based dataset.

Country based data (Scale 1:100 000 to 1:200 000)

A lot of digital mapping still happen from the digitization of features on existing topographic maps. When referencing this information to other sources like the Landsat Imagery, SRTM derived data or GPS drive tracks, some serious topological and cartographic errors can be seen as a result of the mismatch between the different features, for example:
- More accurate GPS road information and the roads from the existing topographic maps
-Correcting only the road information to GPS drive tracks causes an existing river from the existing topographic map to be on the wrong side of the road in some instances
- Correcting the rivers to Landsat imagery causes the rivers to no longer be located in the valleys and ravines as indicated by the existing contour information on the topographic maps

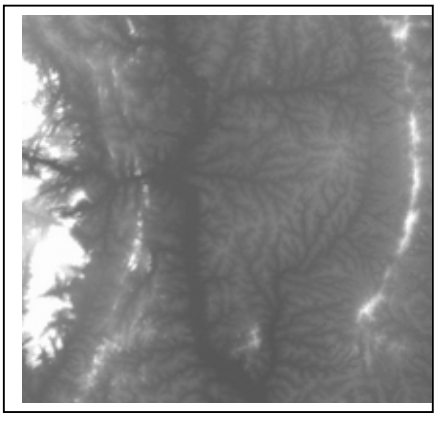
Country based data is now generated from the extraction and overlaying of information from the following sources:

- Existing Topographic Maps
- Landsat TM 7 imagery
- SRTM derived data
- GPS drive Tracks
- Field information

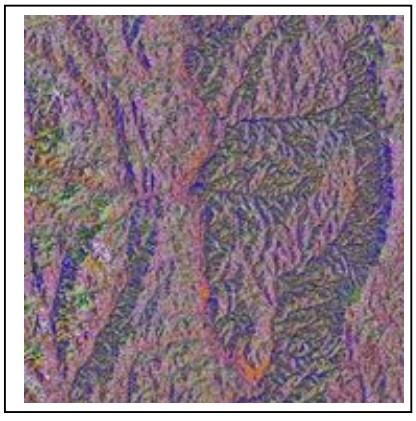
Below is a short explanation on how the major features for Topographic mapping are extracted from the source data:

Contours

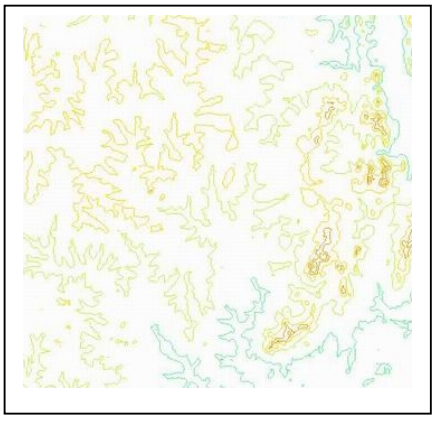
The methodology to create contours involves the creation of a HYDROGRAPHICAL correct DEM (Digital Elevation Model) for each country. The HYDROGAPHIC DEM is built from the latest 90m Radar Interferometric Data (SRTM). Contours (40m or 50m) are then interpolated from the DEM and cross-referenced to the existing ones on the available maps for quality control purposes.



Picture 1: SRTM DEM



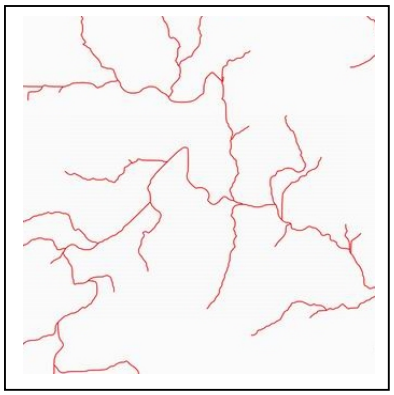
Picture 2: Flow Direction on SRTM DEM



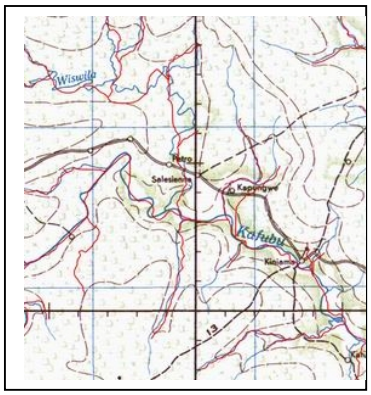
Picture 3: Contours generated from Hydrological correct DEM

Rivers

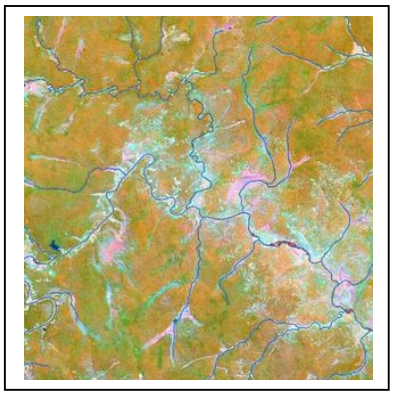
Rivers center lines are interpolated from the same DEM as above, using a Hydrological stream center line creation process. The river center lines created from the Hydrological DEM, as well as the rivers indicated on the existing Topographical maps, are both only used as a reference guideline to capture the new river feature from the Landsat Satellite imagery. New rivers are thus captured from the Landsat Satellite and cross referenced to the Hydrological stream center lines for positional accuracy and to the existing topographic maps to verify the LENGTH and EXISTANCE of a river.
We found that the accuracy of rivers created in this way is better than digitizing it from any map or image alone. The correlation between contours and river lines are also very good as they use the same basic sources of information.



Picture 4: River lines created from Hydrological DEM



Picture 5: Cross reference Rivers to existing Topographic maps



Picture 6: Correct Rivers drawn on Landsat Imagery

Water Areas (Lakes and Dams)

All Water Area features are captured from the existing maps and updated via the Landsat satellite imagery. We ensure that all water areas topologically link to the rivers.

Roads

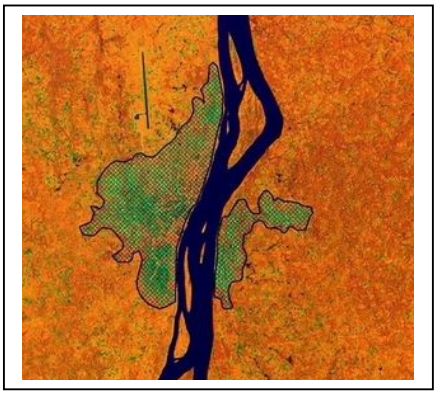
All Road features (except the small Tracks) are captured from the Landsat satellite imagery and using the existing topographic maps as a backdrop reference. Information from GPS track logs is integrated to enhance the spatial accuracy of the roads. The GPS track logs are also essential for the maintenance and classification of the road data. Al road information is captured using a network connectivity rule-base for routing purposes.

Text

Text are captured from the existing maps and cross verified to the NGA Place name database and local knowledge. We also get feedback from the field regarding the changes to text.

Built-up/Urban Areas

All Built-up or Urban areas are classified form the Landsat Imagery and correctly attributed with the applicable text information. We endeavor to store the alternative names sometimes associated to the same built-up area.



Picture 7: Built-up classification on Landsat

Picture 8: Urban expansion from existing maps

Administrative & Other Boundaries

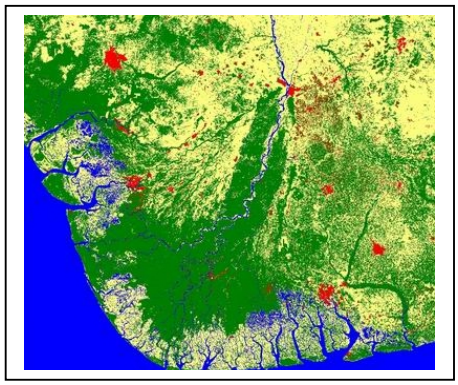
Typically these would be generated with the input from the various local Agencies and Departments within each country. We found this to be a tedious process as the local Agencies and Departments can only broadly indicate the existence of such boundaries.
The boundary data that we do obtain are topologically demarcated to the closest road, river, valley, ridge etc.

Land Use information

All country-wide land use information is classified from the Landsat imagery (we typically use the raw false-color and panchromatic bands for semi-assisted raster classification). The land use information is typically used for military mobility analysis, telecommunication planning (clutter) and various development analysis scenarios.
The number of land use classes in a 40m resolution database can typically range from 6 to 11 classes:

Land Use Description:

Urban (Residential, Industrial, Commercial)
Forest
Low Forest
Low Forest Open
Quasi Open
Open
Bare
Water
Wetland



Picture 9: Regional Land Use in 40m resolution (Nigeria)

City/Town based data (Scale 1:5 000 to 1:10 000)

The methodology for capturing City and Town type data is slightly different from that of the country type data in the sense that it does not need the intensive analytical procedures on for example on the SRTM data for capturing such data. The road rule base for city type data capturing however is more complicated than that of the country data.

Most of the existing maps for smaller nation's cities or towns are so outdated that they need to be captured anew in its entirety. Using high-resolution ortho-rectified satellite imagery combined with GPS field work, is basically the only sources that can be used. If necessary, reference to the paper-based maps for verification purposes are only needed for post quality control checks.

Satellite Imagery vs. Aerial Photography

Although the aerial photography presents the data capturer with a better resolution, the negative aspects of the aerial photography in smaller nations, far outweighs the positive. Not only are the costs higher, but also trying to fly in a hostile nation with necessary permissions for flight plans is a near impossibility. If you do get past the bureaucratic process you will most probably have to pay a military escort flying with you as well. Another problem is the availability and quality of airplane fuel in such countries.
Color satellite imagery that is easily accessible and affordable and from our viewpoint the optimal solution to fulfill the above-mentioned requirements. All city data is captured or updated from the latest available Quickbird, Ikonos or SPOT 5 Enhanced images.

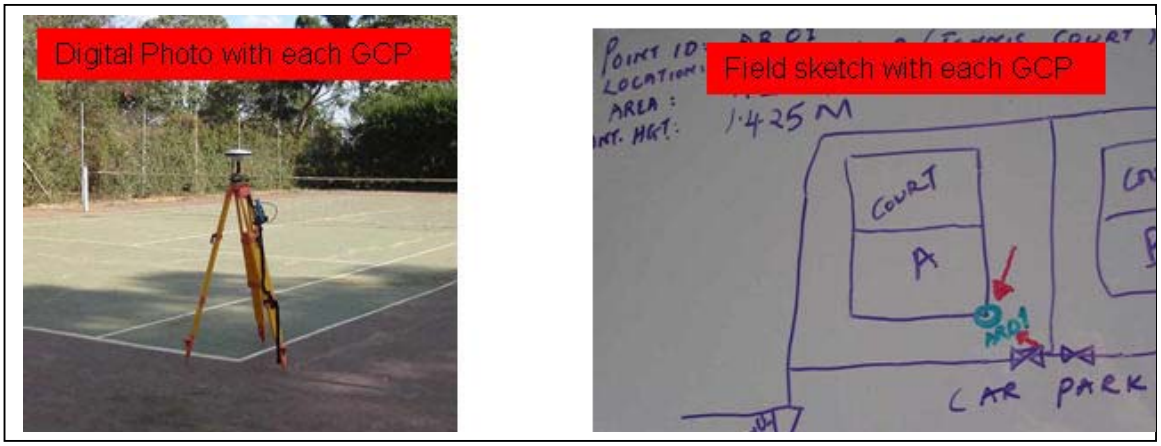
Ground Control Points

Ground control and field surveys are necessary for the geo-rectification of the imagery and obtaining attribute names for the features. This process can present some problems in a smaller nation country. A lot of suspicion can be created when walking around with Differential GPS and logging equipment.
For most of the time, trig beacons or other known surveyed landmarks are either non-existent or vandalized, requiring the use of a real-time differential GPS. This is also an expensive piece of equipment to carry around.

There are basically 2 methods to obtain GPS information for purposes of image rectification:

Differential GPS systems:
A total of between 16 to 20 Ground Control Points (GCP) are collected throughout the city on pre-defined image locations using a differential GPS device. With the differential system we usually try to establish a relationship with a local survey company before entering a country. Differential correction via post-processing of the data allows us to obtain the necessary accurate information in a cost-effective but not always an inconspicuous way, as there is always the risk of the equipment being confiscated.

Single frequency hand held GPS receivers:
Single frequency hand held GPS receivers, like the GARMIN GPSMAP 60 CSX, are used for capturing detailed Track information in un-friendly environments. The Micro SD card within the GPS enables us to generate GPS Tracks at 5m logging intervals without having to worry about loss of data due to memory limitations. Local Taxi's are normally used for driving all the main roads in a grid pattern throughout the entire city. In hostile environments we also sometimes make use of the new GPS-Cell phone to capture Track information.



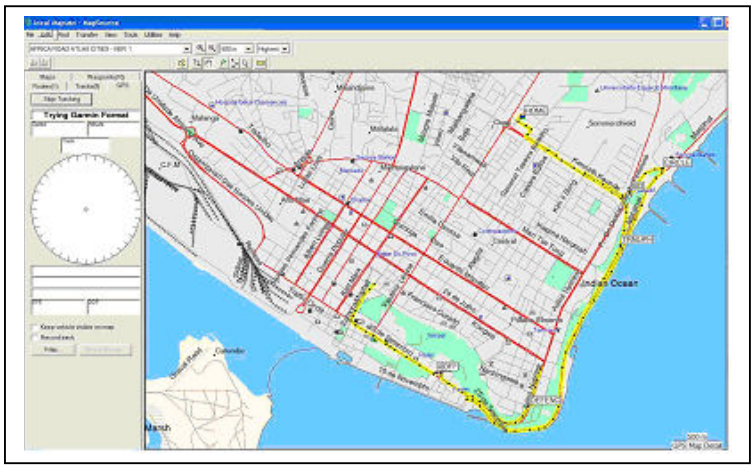
Capture Process

Once we have obtained the imagery and collected the GCP's, the process of capturing spatial data for cities and towns then involves the following:
- Geo-correction of imagery using ground control points and 10m DEMS
- Digitizing of street centre lines according to a rule base (network connectivity)

- Classification of land use and creation of polygons
- Land use creation and classification
- Cartographic styling of the data

Field Collection of Attributes

We currently use the MPC Map Generation toll from Garmin to assist us with our field work methodology. The MPC tool not only allows us to not only create GPS Mapping Products for the retail and commercial markets, but also to upload our raw captured map data into a map-enabled GPS for field attribute collection. The field worker can thus capture attributes with Roads, Streets and Land Use information as a backdrop in his map-enabled GPS. The process of uploading the attributes to a PC and integrating to the GIS – is a simple procedure minimizing errors of human interference.



What Standards and Formats are used?

The Standards for Topographic Feature and Attribute classification has been adopted from various existing Topographic Map Standards in the market – but with a lot of simplification involved. We are in process to migrate the data to a European accepted standard.

For Routing purposes, we also expand the Road features classification according to the TeleAtlas Multinet shape format.

Below find a summary description of the features used in a common Topographic Dataset:

ADMINISTRATIVE LAYERS

Value	Description
COUNTRY_BNDS	Country Boundaries
PRV_STATES	Provinces or States
ADMINBOUNDS	Community or Other Administrative Boundaries
LOCALBOUNDS	Metropolitan or Greater Town Boundaries
TOWNBOUNDS	Town Boundaries
SUBURBS	Suburb or city subdivision boundaries
TOWNS	Center points of towns and places of habitation

ROADS

Road Types

Broad road groupings, used internal for basic styling and attribution during capturing

Value	Description
Major	Major road network through country, usually styled blue and includes most freeways
Main	Provincial road network, major and other city and town through routes
Road	All other roads that can be traveled by car (in countries where routable data is available all these roads are routable)

Other	In countries where routable data is available, all roads that are not routable.
Track	Non routable roads and dirt tracks that are of uncertain quality and usually only accessible by off-road vehicles
Rural	Rural walkways and tracks that are not routable and not used by motor vehicles. Includes walkways in informal settlements / squatter camps.

Road Classification

Road surface condition

Value	Description
P	Tarred or paved
U	Un-tarred or un-paved
UC	Under Construction
UNK	Unknown

WATER AREAS

Functional classification of water areas

Value	Description
Canal	Man made water passage used by boats to travel between water areas (Canal must be broader than 10m in urban areas and 25m in regional areas)
Dam	Man made water feature where a wall is evident to dam water
Harbour	Man made water area where boats dock, usually with a narrow entrance to the ocean or lake
Lagoon	Water body that is connected to the ocean by a narrow channel
Lake	Perennial water body not greatly affected by seasonal changes and may be fed by a perennial river or stream and may have an outflow
Marsh	Marshy or boggy area that can be occasionally inundated, usually low-lying and often surrounding an open water area (See Vlei)
NP	Non-Perennial River water area (>25m in regional areas and ~>10m in urban areas)
P	Perennial River water area (>25m in regional areas and ~>10m in urban areas)
Pan	Water body that is seasonal or partially seasonal that is natural (no dam wall) and is not fed by any perennial river or stream, and does not have a perennial outflow
Reservoir	Reservoir
SaltPan	Man made open-air structure used to extract salt from sea water by evaporation
SlimesDam	Mine area where sediment is left to settle out
SW	Sewage Works and water treatment plants
Vlei	Smaller marshy region surrounding a stream or river that are occasionally inundated when the river is in flood
Water	Very small (~<50m) natural water area without a noticeable man-made wall

RIVERS

Classification of rivers (water lines)

Value	Description
Canal	Man made water passage used by boats to travel between water areas
DamWall	Man made construction used to contain water into a dam
NP	Non-perennial rivers
P	Perennial rivers

PARKS

Classification of parks

Value	Description
National	Official parks residing under country authority or of national significance
Regional	Official parks residing under provincial or local authority or of provincial or local significance
Conservation	Conservation areas where land is set aside for conservation, but local residents are usually permitted to stay
Private	Private game reserves, ranches and lodges. Can include adventure farms set aside for conservation
Marine	Marine park or conservation area. Mainly for styling purposes. For parks that stretch across the coastline into the ocean, two polygons are drawn - one extending to the country boundary and the other extending into the ocean.
City	Open space in urban areas set aside for public relaxation. Either natural or constituting a garden. Excluding formal sports grounds. Excluding reserves where wild animals are kept. Excluding animal or bird sanctuaries
BotanicalGarden	Formal botanical gardens where research is carried out
Sanctuary	Animal or bird sanctuary. Terrain is usually freely accessible to pedestrians and no stay in vehicle rules in place
SPSA	Society for the Prevention of Cruelty to Animals and other animal pounds.
ZooAqwarium	Zoo or Aquarium grounds

LANDUSE

Classification of landuse

Value	Description
Commercial	Areas covered by shopping centres and other commercial activates (Not Named, name in POI)
Industrial	Whole industrial areas and no just the buildings (Not Named)
Cemetery	Cemeteries and other burial yards (Named, but POI entry must be present)
School	School, university or college ground (Not Named, name in POI
Airport	Airport and airfield grounds (including buildings) (Not Named, name in POI)
Runway	Aircraft runways surface (does not include vehicle access roads)
Racetrack	Racetrack surface (Not Named)
MineDump	Mine dumps and other slag heaps (Not Named)
Golf	Golf course ground (Named, but POI entry must be present)
SportBuilding	Sport Stadiums and Complexes (Named, but POI entry must be present)
SportGround	Sports grounds without significant stadiums or complexes. Grounds with singe pavilions and / or club houses are included. Tennis Clubs are included. Sports facilities that form part of school grounds are not included. (Named, but entry must be present)

TOWN TYPES

Value	Description
CAPITAL_CITY	City or Capital

MAJOR_TOWN	Big town
SECONDARY_TOWN	Smaller town
OTHER_TOWN	Smallest towns
SETTLEMENT	Place of habitation

BUILT UP AREAS

Currently only used in South Africa and is not complete

Value	Description
formal	Formal urbanised areas
informal	Informal settlements and squatter camps
small_holdings	smallholdings

RAILWAYS

Classification of railway lines

Value	Description
RLW	Normal railway line
SID	Siding
NARROW	Narrow gauge railway

TOPOGRAPHY

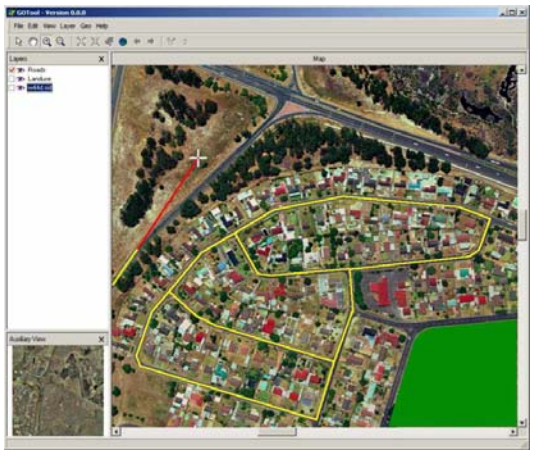
Value	Description
Contour	Contour Height in meters

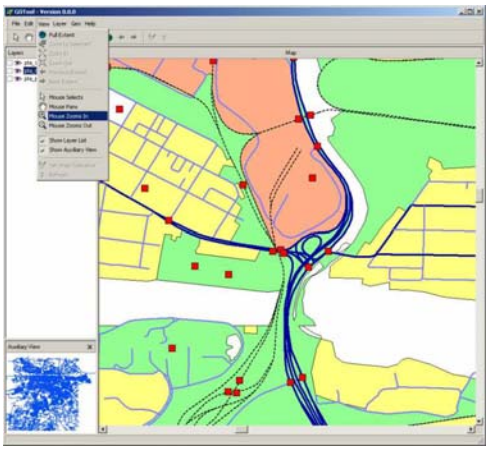
What software and equipment are used?

The commercial high-end GIS software can provide most of the functionality needed for a bulk capturing project, the problem however is that they also provide you, at a cost, with a myriad of other GIS functionality not necessarily needed. The price of high-end GIS software, as well as specialized data capture functionality required, forced us to develop our own data capture tool called GoCapture. The GoCapture software incorporates best data capture functionality similar to popular GIS software like GeoMedia, Esri ArcInfo and MapInfo.

The software has capability to handle complex data capturing requirements:

- rule base capturing (lines, polygons, points, snap-tolerance, follow geometry, re-digitize, self intersecting,)
- data manipulation (split, merge, delete, clip doughnuts/islands, move, change line direction, change feature class)
- easy attribute assigning & editing (including pre-loaded dropdowns on any field)
- image loading and visual map-projection of vectors
- post-and pre styling of layers
- more than 20 capturers simultaneously linked to a SDE Database
- quick zooming and panning
- query building functions





How is the data updates maintained?

It is virtually impossible to maintain the data on a continental scale by trying to do it all by yourself.

We have developed 4-fold data maintenance approach:

- Establish Commercial partnerships with local GIS/Survey firms
  By developing a business case with financial incentives around the commercial aspects of the data, e.g. GPS applications, Vehicle tracking, Data sales etc, we have found eagerness from interested firms in the developing countries wanting to partner with us. Such incentives would typically involve a 30% sales commission on all types of data business and in turn we get the local support in terms of attribute and other data collection necessary for the maintenance of a dataset.

- Utilize the Vehicle Tracking clients
  Technology now offers GPS chip sets with a high data collection frequency in the vehicles being tracked, weather it be downloaded via GPRS, Radio, Satellite or a post trip exercise. We have found an eagerness from all our vehicle tracking clients wanting to provide us with their GPS track and waypoint data, understanding the problems of data capturing in a continent like Africa and Middle East and in bettering the map database also for their own benefit.

- Mobilize the GPS Web Community
  Some of our data gets integrated into products like Garmin's MapSource GPS product. This product allows for Route and Destination planning on a PC or GPS device, and also has the capability to log the Track and Waypoint data for a recreational or business outing. Having requested Garmin to allow us to log the user's name and email details when unlocking the software to the GPS unit, we can now interact with a user community of 50 000+ users, and growing at a rate of 3000 to 5000 per month. Regular newsletters and a very active Web forum, informs new users of the latest developments in GPS and mapping, and also request users to upload or mail us their Track logs and Waypoint data. Again we have had a very positive response from the user community in Africa, as most users are blown away by the latest navigation and mapping technology available for a country where it use to be difficult to even find a decent paper map.

- Traditional Drive Tests where necessary
  Traditional Drive Tests by our own field staff is always necessary to ensure the quality and routing integrity of the data offered. Drive Tests are time consuming and expensive, but with proper logistical planning the costs can be kept at bay.

Costing for Full Topographic and Commercial datasets?

The costs for the spatial data as per country can vary according to a client's specific need, e.g. Military organizations typically would be interested in full Topographic dataset, whereas a Vehicle Tracking client might only be interested to obtain the basic features of Roads, Admin Boundaries, Towns and Main Rivers (what we would call a Commercial Dataset) The price range for a full topographic dataset (Africa and Middle East) can vary from as little as $ 9000 for a small country like Djibouti, or as much as $ 250 000 for a large and fieldwork intensive country like Democratic Republic of Congo. The price range for a commercial dataset for the same countries would vary from $ 4000 to $ 34 000. Costs for detail city data can also vary from as little as $ 8000 for as smaller African city, to as much as $ 28 000 for a large city like Lagos. Standard License conditions apply.

Cheap alternative product incorporating this data

There are a few cheap product solutions for those wanting to obtain the data at a fraction of the true value. The popular products are those that incorporate the data in a propriety format offer various degrees of analysis – via PC or GPS - on the data e.g. Viewing, Routing, Navigation, Styling, Printing etc. The data

however cannot be incorporated into a standard GIS for purposes of editing and GIS analysis. It does however off the end user a cheap solution for basic mapping.

The prices for the mapping product will typically be in the range of $ 100 per CD of Memory card.

Currently mapping solutions, incorporating country and detail city data for well known brands like GARMIN, TomTom, MIO and Map & Guide, is currently being offered in the market.

Conclusion

By utilizing and intelligently combining sources of relative cheap data from available topographic maps, SRTM derived data, GPS field data and archive satellite imagery, new base maps can virtually be created for any country or city in the world. By networking and establishing a financial business case with local businesses in each country – or region – the data can actually be maintained and improved by detecting the changes and expanding the attributes in the database. New technology and improvements in the arena of GPS (Galileo) and satellite imagery can only further enhance the quality and rate of data capture projects. As a private an independent provider of spatial data to an international client base, both in terms of Military and Commercial customers – we have to look at the most affordable sources of data providing us with the highest quality results. We however strongly believe that the future base mapping requirements for both customers will be exactly the same: An intelligent Routable Topographic Database.