Open Source Algorithms for 3D Geo-Representation of Subsurface Formations Properties in the Oil and Gas Industry

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Abstract—This paper presents the result of the implementation of a series of algorithms intended to be used for representing in most of the 3D geographic software, even Google Earth, the subsurface formations properties combining 2D charts or 3D plots over a 3D background, allowing everyone to use them, no matter the economic size of the company for which they work. Besides the existence of complex and expensive specialized software for modeling subsurface formations based on the same information provided to this one, the use of this open source development shows a higher and easier usability and good results, limiting the rendered properties and polygons to a basic set of charts and tubes.

Keywords—Chart, earth, formations, subsurface, visualization.

I. INTRODUCTION

O IL and Gas Industry bases the upstream operations on drilling and developing wells so as to extract the most of the hydrocarbons at the best economic possible rate

This includes knowing where to drill, how deep to drill, what deep to perforate, decide whether or not to stimulate, where to plug, etc.

In order to help geoscientists and geologists to determine all these parameters, one century ago Mr. Conrad and Mr. Marcel Schlumberger [1] created the science of what they called "Electric Coring" or "Electric Logging" that consisted on lowering measuring tools and devices down the hole using a wire, measuring and acquiring information of the subsurface borehole walls, mud and deep into the formation.

At that time measurements were limited to determine the Spontaneous Potential [2] of the wellbore at each stage of deep, but nowadays involved measurements and determinations include caliper readings, formation resistivity, density, natural radioactivity, porosity, oil, gas and water saturation and dozens of other items belonging to the intrinsic characteristics of the drilled formations.

For that purpose the industry uses tools designed to use physics and its different disciplines like Sonic, Ultrasonic, Electrical Induction, Magnetic Resonance, Gamma Ray Detectors, Neutron Generators, Spectroscopy, Live Fluid Analyzer, and Formation Pressure measuring sondes among many others ones [3].

The output of all that measures take the form of a regular chart, plotting the variables in the Y axis vs the Dept in the X,

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but, as they are intended to plot the whole well deep interval, those charts, and combination of charts sometimes are dozens of meter long, or even more in the used vertical scale is only 1:40, or 1:200. See Fig. 1.
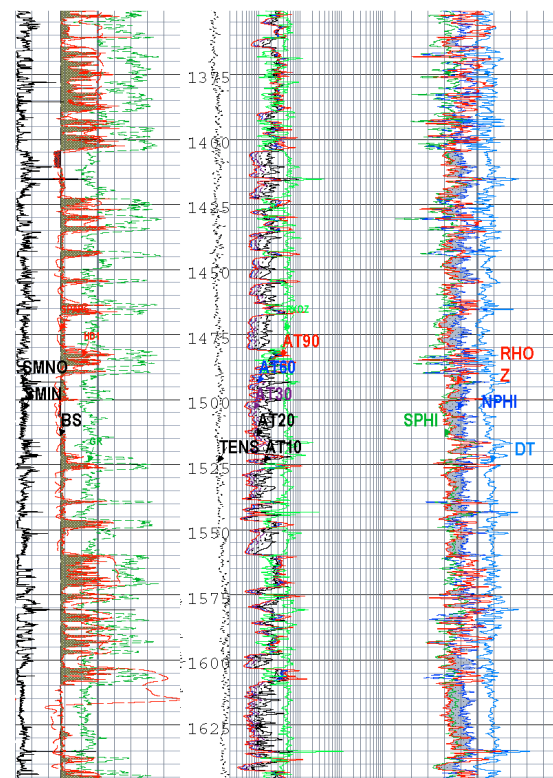

Fig. 1 Standard composite log

There are several commercial software packages that can feed databases in order to produce a 3D render of the subsurface formation based upon several well logs. The main issue of using those packages is that they are too expensive for small companies, sometimes up to 100Kusd, and require a special training program so as to let the users start doing those renders.

The software that is being presented is able to create just a little part of the huge battery of visualization capabilities of them, but instead is too easy to operate, it has no cost at all, and results can be shared among users and non-users in the form of simple kml files.

II. GEOTAGGING OIL AND GAS WELL LOGS

A. Data Structure and Visualization

Despite the fact that acquired data is mainly used in the form of graphical logs, or charts, the implicit dataset is stored inside industry-proprietary database files called DLIS files that could be compared to databases files, populated with several tables that we call "frames", and in each table myriads of parameters and channel values are stored, like calibrations, well placement, latitude, longitude, measured values, serial numbers of the instruments, logging date, etc.

In order to plot those files in most of the freeware geographic software, using Visual Studio 2013, the author has created a piece of software that uses an algorithm that looks inside the content of each DLIS file, extracting those geographic parameters like latitude, longitude, altitude, depth of the well, and coordinates system definition transforming the information that lies within into KML files ones, that let users create single representations of well placements in the basin.

This kind of representation only pots the position of the well heads on an application like Google Earth. See Fig. 2.
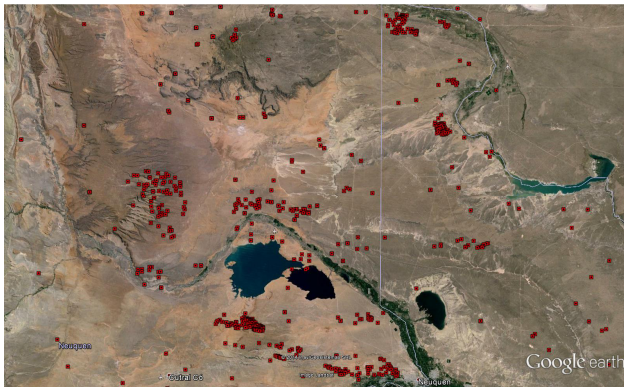

Fig. 2 Well placemarks in the basin

In order to create the representation of the subsurface formation characteristics we have to choose which characteristic to plot (porosity, density, saturation, gamma ray, corrosion, etc. This is done by clicking on the list of pre-selected characteristics (or channels) form a drop-box, and once selected, the other parameters have to be chosen for the visualization to be customized like the color schema, type of representation (2D East-West horizontally scaled charts, or 3D polygons), minimum and maximum value for the channel scale, and the number of geographical degrees this scale should cover. See representations like Figs. 3 to 5.

As many geographic software packages don't allow drawing shapefiles under the earth surface [4], the convention is to plot the characteristic charts as a "mirror" projecting to the zenith the subsurface upwards-down, so shallower depths are represented nearby the soil.
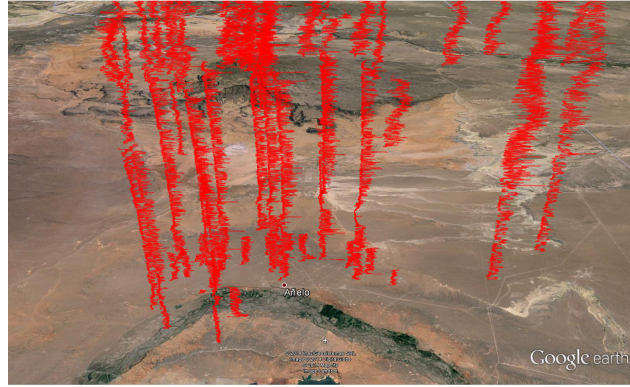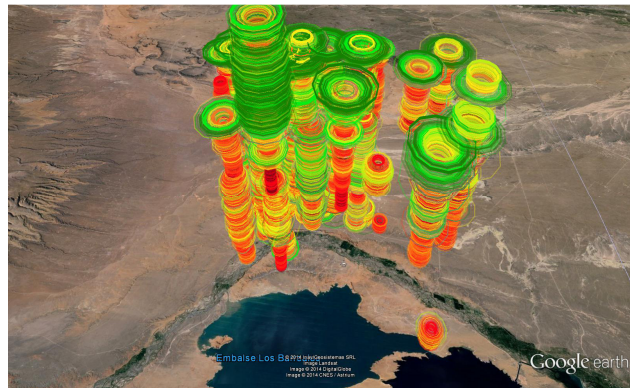

Fig. 3 Log view of selected channel

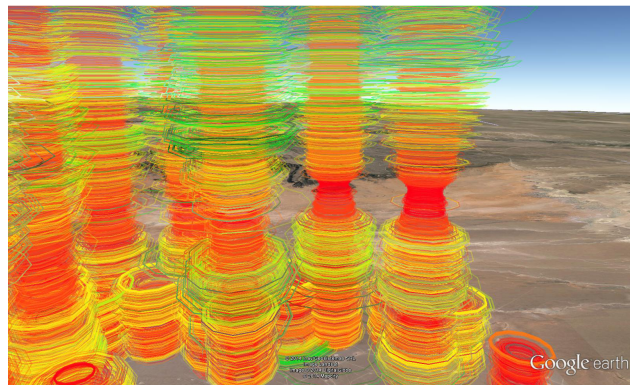Fig. 4 3D Tube representation of channel values

Fig. 5 Tube view detail

B. Directionally Drilled Wells Representation

Defining directional Drilling, Schlumberger states *'The intentional deviation of a wellbore from the path it would naturally take. This is accomplished through the use of whip stocks, bottom hole assembly (BHA) configurations, instruments to measure the path of the wellbore in three-dimensional space, data links to communicate measurements taken down hole to the surface, mud motors and special BHA components and drill bits, including rotary steerable systems, and drill bits'* [3]. More often than ever wells are being drilled not only vertically, but also horizontally, or aiming a target in the subsurface using this technique.

Well path can drift thousands of meters east/west or north/south of the top of the well head position (Fig. 6).
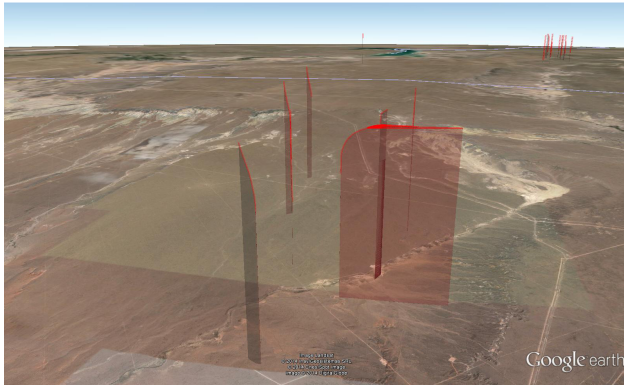

Fig. 6 Directional drilling drift representation

C. Graphical User Interface

In order to let the system plot the desired properties, involved algorithms [5] have to be indicated what scales to use, what colors, what channels and what wells to represent, for this selections user has to use this form where the user specifies each customized parameter to be used in the representations. (Fig. 7)

For well selections, the database has to be queried pre-selecting those wells going to be geotagged, and the method will loop reading all the values for each one of the well head placements creating the visualization for all of them.
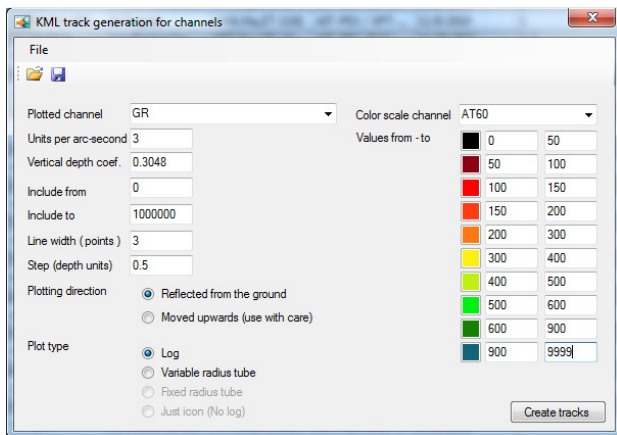

Fig. 7 Graphical User Interface

D. Algorithm and Method

In order to create the 3D chart over the well location, we are modulating the Easting (Longitude) in order to match the scale of the chosen variable, and the vertical scale is the real one, but inverted as mirror upside down.

For the header of all kml files we use the following header as part of a standardized representation:

```
<?xml version="1.0" encoding="UTF-8"?>
<kmlxmlns="http://earth.google.com/kml/2.2">
<Document>
```

```
<name>WELLNAMECHANNELBehaviour</name>
<StyleMap id="msn_ylw-pushpin">
<Pair>
<key>normal</key>
<styleUrl>#sn_ylw-pushpin</styleUrl>
</Pair>
<Pair>
<key>highlight</key>
<styleUrl>#sh_ylw-pushpin</styleUrl>
</Pair>
</StyleMap>
<Style id="sh_ylw-pushpin">
<IconStyle>
<scale>1.1</scale>
<Icon>
<href>http://maps.google.com/mapfiles/kml/pushpin/ylw-pushpin.png</href>
</Icon>
<hotSpot x="20" y="2" xunits="pixels" yunits=" pixels"/>
</IconStyle>
<LineStyle>
<color>4c0000ff</color>
<width>3</width>
</LineStyle>
<PolyStyle>
<color>4c0000ff</color>
<outline>0</outline>
</PolyStyle>
</Style>
<Style id="sn_ylw-pushpin">
<IconStyle>
<scale>1.3</scale>
<Icon>
<href>http://maps.google.com/mapfiles/kml/pushpin/ylw-pushpin.png</href>
</Icon>
<hotSpot x="20" y="2" xunits="pixels" yunits=" pixels"/>
</IconStyle>
<LineStyle>
<color>4c0000ff</color>
<width>3</width>
</LineStyle>
<PolyStyle>
<color>4c0000ff</color>
<outline>0</outline>
</PolyStyle>
</Style>
<Placemark>
<name>WELLNAME-CHANNEL Behaviour</name>
<styleUrl>#msn_ylw-pushpin</styleUrl>
<LineString>
<extrude>0</extrude>
<tessellate>1</tessellate>
<altitudeMode>relativeToGround</altitudeMode>
```

For the 3D tubes, the modulation is done in the radius of the created polygons defined by looping n times through each

depth step (n is the number of sides of the polygons that are created), by default n=12, all along the depth interval. Note that the file-size of the generated placemark will be n times bigger than the version created using only East-West modulation.

<coordinates>
(Looping the whole depth-interval)

$$\text{For } z = 0 \text{ To } (2 * \pi) \text{ Step } (2 * \pi / n) \qquad (1)$$

$$\varphi ii = Sin(z).c.(Ms - ms).yi + \varphi 0 \qquad (2)$$

$$\lambda ii = Cos(z).c.(Ms - ms).yi + \lambda 0 \qquad (3)$$

$$hii = h0 + di \qquad (4)$$

text = text &λii,φii,hii,
Next z
text
(Finishing the loop)
</coordinates>
</LineString>
</Placemark>
</Document>
z is a simple radians counter for the circular loop
$\varphi 0$ is the latitude of the well head
φii is the calculated latitude of each point of the polygon
$\lambda 0$ is the longitude of the well head
λii is the calculated longitude of each point of the polygon
h0 is the elevation of the well head
hii is the calculated elevation of each point
di is the depth of each point
c is the geographic scalability constant (3600 seg^{-1})
Ms and ms are the Maximum and minimum scale value
yi is each measured value of the selected channel
And for the modulated values involving the visualization in a linear scale [6] each point is plotted calculating its coordinates based on (5) to (7) using single points instead of polygons, so the need for looping around each depth step is not needed:
<coordinates>
(Looping the whole depth-interval)

$$\varphi i = \varphi 0 \qquad (5)$$

$$\lambda i = \lambda 0 + c.(Ms - ms).yi \qquad (6)$$

$$hi = h0 + di \qquad (7)$$

text = λi,φi ,hi
(Finishing the loop)
text
</coordinates>
</LineString>
</Placemark>
</Document>
φi is the calculated latitude of each point
λi is the calculated longitude of each point

hi is the calculated elevation of each point
The method involves scanning trough the database all the selected wells, and looping by them creating the kml place marks for each one of them using previous described algorithms.

III. CONCLUSION

This Open Source development proves that there is plenty of space to keep on improving collaboratively the way our Data Centers share and shows our geo-represented datasets.

It helped many locations users, and could help on triggering many customizations for any other industry or requirement.

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