

Data Visualization for Oil and Gas Pipeline Anomalies and Repairs using R Shiny

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Abstract

In-line inspection (ILI) tools are used to help assess areas of a pipeline that might need remediation. ILI tools are run through the inside of the pipe and typically utilize ultrasonic or magnetic flux technology. As the ILI tool (often called a pig, and hence this process is termed “pigging”) moves down the line, the signals are sent via transducers to the inside pipe wall. These signals travel into the wall and help identify different types of anomalies, such as internal/external corrosion and seam weld defects. The time it takes for the signal to bounce back to the onboard computer is used to quantify the extent/severity of a given anomaly. The anomalies are sized into “boxes” based on the length and width the ILI tool measures around each location. One of the methods used to estimate corrosion growth between subsequent pig runs, which is critical in the overall integrity management of pipelines, is size and depth comparison of these boxes. The R Shiny BoxIt app is a web application that dynamically responds to the user inputs and provides the pipeline industry a visualization of multiple ILI runs to aid in identifying matching anomalies over time.

Key Words: Oil, Gas, Pipeline, visualization, in-line inspection, pig

1. Introduction

Risk assessment for oil and gas companies often involves analysis of the structural integrity of transportation pipelines. Because it is cost-prohibited to visually assess the condition of underground pipelines, ILI data play a large role in estimating integrity. Most pipelines are pigged (ILI tool run) every five or seven years, depending on the product, unless there are concerns that would lead to more frequent inspection.

It is difficult for many pipeline operators to be able to “see” the results of a single ILI run other than having an Excel table provide information about the anomalies detected. ILI vendors provide software to aid in the visualization; however, it is specific to the ILI company’s system and takes a trained eye to read the signal data, which often look like heart EKG patterns. Furthermore, these tools do not generally allow viewing of more than a single ILI run even if the same vendor’s tool was used in the ILI runs.

Some larger oil and gas pipeline operators use geographic information systems (GIS) to allow multiple data sets to be overlaid, such as two different ILI runs. In practice, even with large operators, it has proven difficult to get the needed GIS support to easily and quickly show such displays. In addition to ILI data such as length, width, and depth of varying anomaly types, other information may be available that might aid the determination of areas of the pipeline that warrant further study or excavation, which is very costly. Such data includes excavation measurements, repairs, and close interval (above ground) surveys.

At conferences and interactions with clients, it became apparent that an easy-to-use software tool would be welcomed by many users. Such a tool would also have wide applicability in providing useful insights in the interpretation of large spatial data sets composed of potentially many differing types of data.

R (Wickham and Grolemund, 2017 [1]) is a free open source package used in numerous data sciences projects and handles large data sets. This is an important aspect in being able to incorporate potentially many years of ILI and related data. It was determined that an R Shiny (RStudio, 2017 [2]) application would provide the desired capabilities on an easy-to-use web environment. Shiny is a R package specifically designed to provide a development framework that allows complex web apps to be created without detailed knowledge of html, CSS, java and other standard web methods. An attractive and responsive user interface may be achieved with Shiny. One requirement for Shiny applications is that a Linux environment is necessary for the required Shiny server. This can be addressed in several ways that are beyond the scope of this paper.

BoxIt currently is a visualization only tool that allows multiple ILI runs to be seen simultaneously as well as depicting repairs and other desired pipeline information. The main requirement is that all the data be aligned to the same spatial coordinates.

The bulk of this paper describes some of the BoxIt capabilities. A pre-populated BoxIt with pseudo data (BoxIt demo, 2019, [3]) is available on the web that allows one to use the software to obtain a more in-depth view of its capabilities. An accompanying four-minute video is also viewable on the web (BoxIt video, 2019, [4]).

2. Illustration of Key BoxIt Output

A software tool not described here allows users to input their data into an Excel template that then produces an output file in the format required by BoxIt. Once the BoxIt-ready file is uploaded to BoxIt, the plot of the first pipe segment (“joint”) with data is produced, as shown in Figure 1. Joints of pipeline are different grades of steel in varying diameters and wall thicknesses and are often around 40 feet long. Figure 1 is a portion of a pipeline showing ILI data from both 2012 and 2017. Rectangular boxes are shown for corrosion anomalies for the two years. The 2012 data are colored orange and the 2017 data are blue. Vertical lines represent girth welds where the ends of two different pipe joints are welded together. Most joints are constructed with longitudinal seam welds that run the length of the joint and could be visualized in BoxIt as a horizontal line if this data is captured in the ILI run.

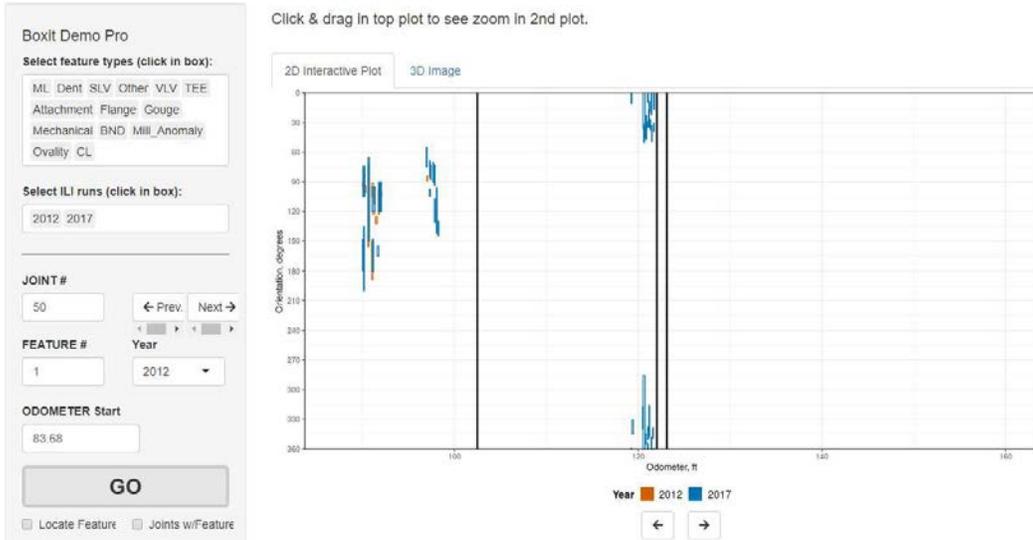


Figure 1: Sample initial plot produced in BoxIt with some controls seen on the left.

The “Select feature types” control initially contains all anomaly types as well as repair and replacements (collectively called “features” in the pipeline industry) found on the particular pipeline. Users can decide which features to display on the plot. In this example, there are data from two ILI runs, but users can plot up to eight different data sets. Not all features are represented by rectangles. For instance, sleeves (“SLV” in “Select feature types”) are represented by a light grey rectangle that covers a full circumferential section of the pipe, as depicted in Figure 2. In Figure 2 and most of the subsequent plots, the controls the user would see on the left of the screen are not shown.

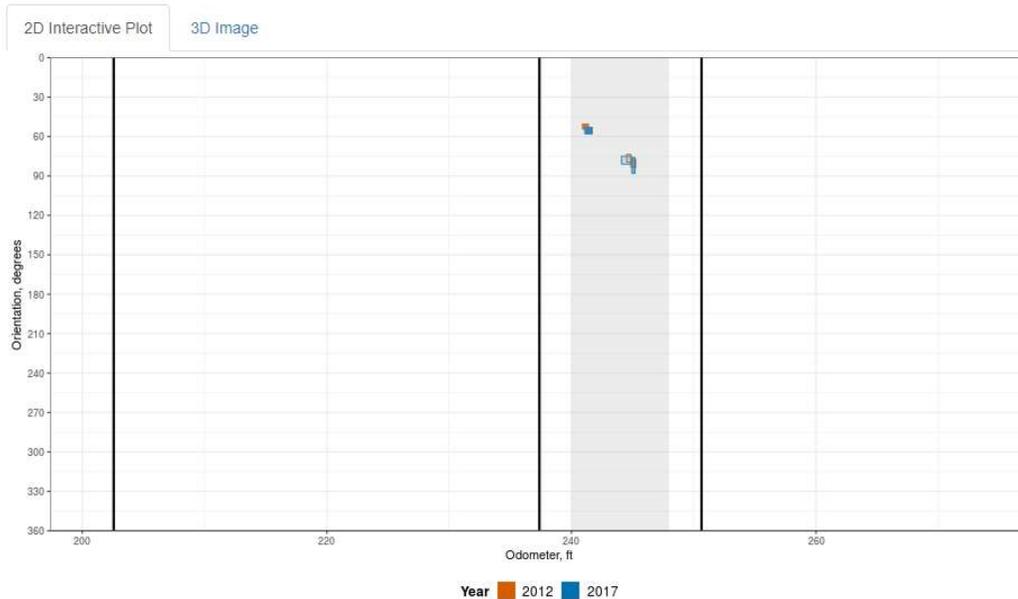


Figure 2: BoxIt plot including a sleeve completely covering a given circumferential area.

Diverse graphical images are used to allow easy visual differentiation of feature types. Colorblind-friendly colors and different line types help the visual assessment. Only a small subset of such is seen in this paper and the reader may want to view the demo BoxIt software and associated video discussed earlier for additional visualization capabilities. For example, dents are represented by ellipses, as seen in Figure 3. This dent located at the top of the pipe is hard to visualize as is. This is addressed in Figures 3 and 4 using the BoxIt rotation control.

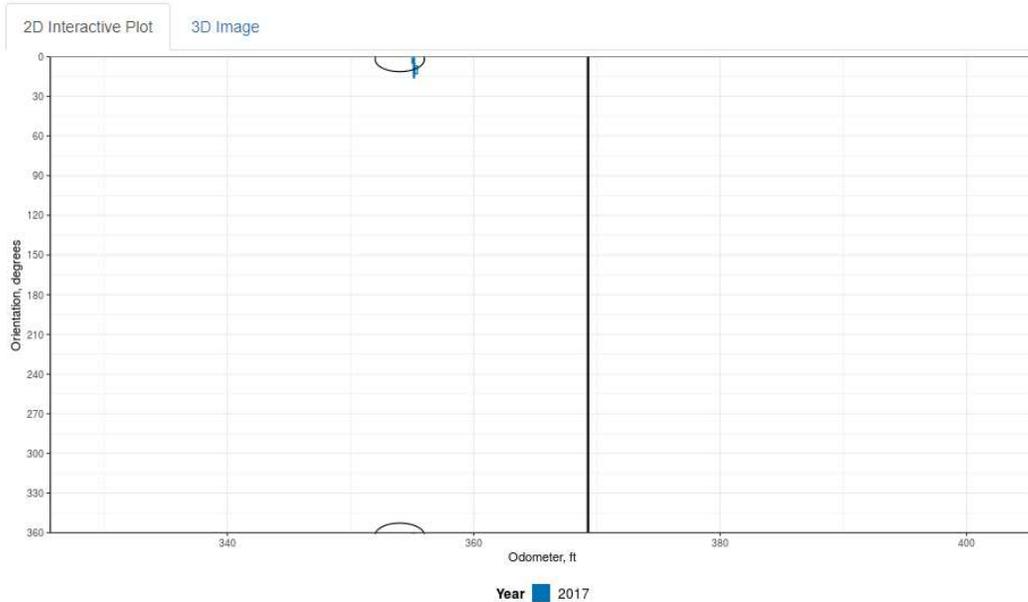


Figure 3: Example of a dent, represented by an ellipse, that is at the top of the pipe.

The “Rotate pipe (30 deg)” (Figure 4) allows any degree of rotation; however, the up/down arrows allow a quick click for 30 degree rotations.



Figure 4: Pipe rotation allows better viewing of anomalies crossing top of the pipe.

Figure 5 depicts the same part of the pipeline in Figure 3 rotated by 90 degrees, providing a clearer view of this dent.

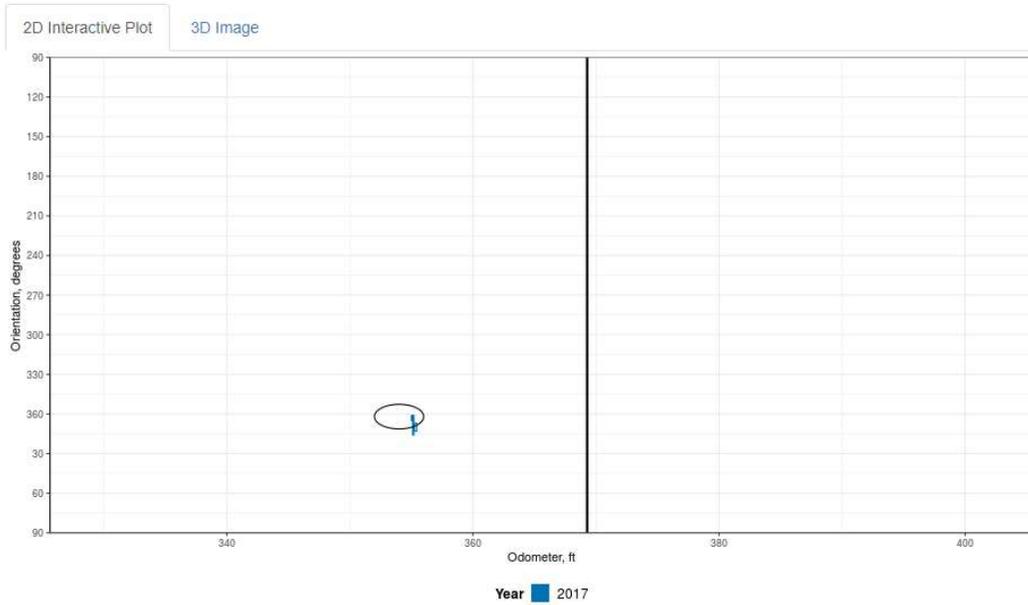


Figure 5: Pipe rotated by 90 degrees, providing better view of dent at the top of the pipe.

Figure 1 provided a more global view of the main BoxIt plot and some of the controls, both to the left of and below the plot. Using the left and right arrows under the plot, the user can move the plot up and down the pipeline. However, if the user is interested only on the joints that have features, the user can check the box “Joint w/Features” and then go to the next or previous joint with data by using the “Prev/Next” arrows shown in Figure 6. Many pipelines have features only on a small subset of joints and thus having this flexibility can reduce the time needed to review a given line.

Figure 6: BoxIt controls to show navigation to joints that have features.

There are several modes to navigate to desired locations along the pipe, such as by joint number, feature #, odometer, or other controls not shown. If the user inputs a joint number

not in the data set, the JOINT # box will turn red and the “GO” button will be disabled and say “INVALID JOINT,” as shown in Figure 7. The same behavior will occur for an invalid Feature # or Odometer input value.

The screenshot shows a web form with the following elements:

- JOINT #**: A text input field containing '6078', which is highlighted in red.
- Navigation**: Two buttons labeled '← Prev.' and 'Next →'.
- FEATURE #**: A text input field containing '1486'.
- Year**: A dropdown menu showing '2017'.
- ODOMETER Start**: A text input field containing '325.59'.
- Error Message**: A large, prominent red button with the text 'INVALID JOINT'.
- Checkboxes**: Two checkboxes at the bottom, labeled 'Locate Feature' and 'Joints w/Features', both of which are currently unchecked.

Figure 7: Invalid joint identification by BoxIt in response to user input error.

The user can highlight any portion of the plot that is of interest by clicking and dragging over an area. A second zoomed plot and associated data table will appear under the top plot. This is especially helpful to take a more in-depth view of a particular part of the pipeline. Doing so helps the visual assessment of features that might align between two or more ILI runs. The data table contains important information of the highlighted features that can be used for integrity assessment. Figure 8 shows a main plot with a brushed area in light blue near the bottom middle of the figure with a red arrow pointing to it.

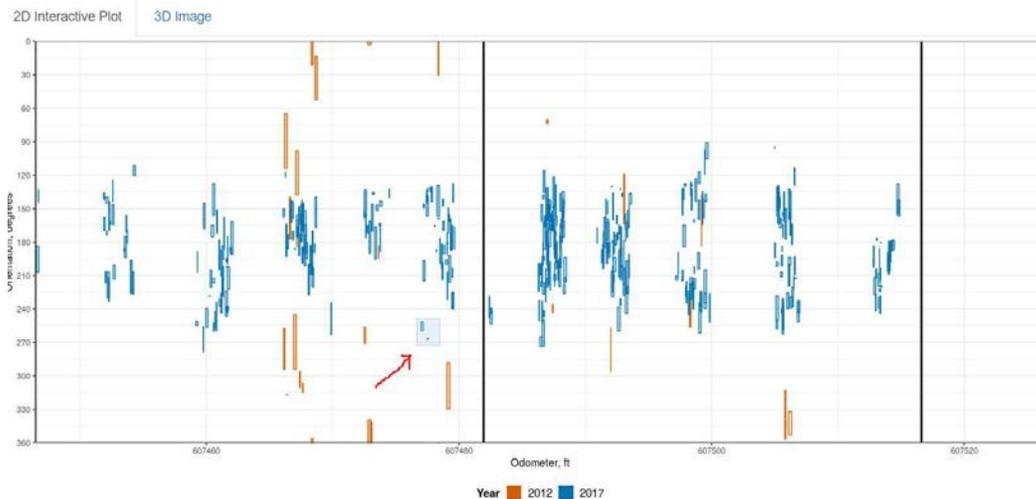


Figure 8: Main plot showing a brushed area to be shown in the zoomed plot.

The resulting zoomed plot that appears under the top one from Figure 8 is shown in Figure 9. There are a variety of control (not shown) to the left of the zoomed plot that allow the user to change the plot characteristics.

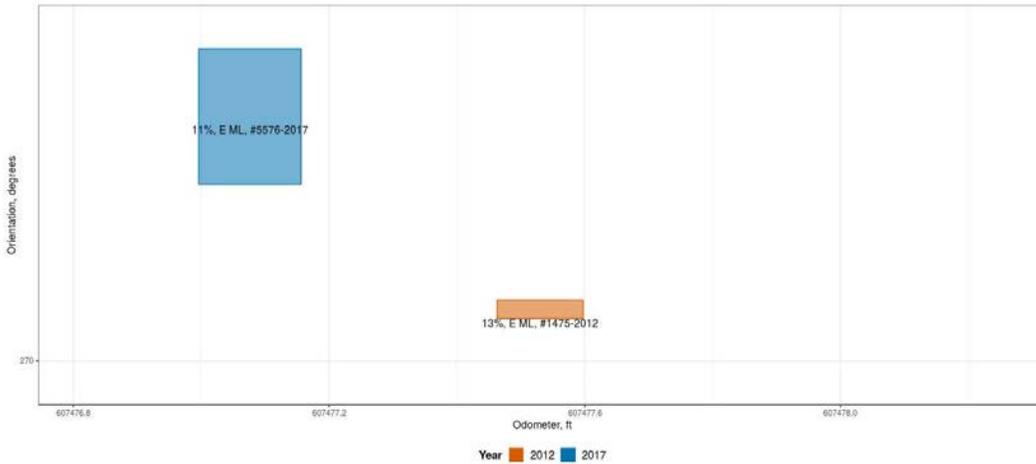


Figure 9: Zoomed plot from brushing main plot shown in Figure 8.

An option called “Zoom: Depth text shown?” can be toggled off to remove the overlaid text on the boxes. Furthermore, the user can zoom again inside the zoomed plot to get an even more detailed look at the selected region of the pipe. Figure 10 shows a smaller region of the plot presented in Figure 9 with the text disabled.

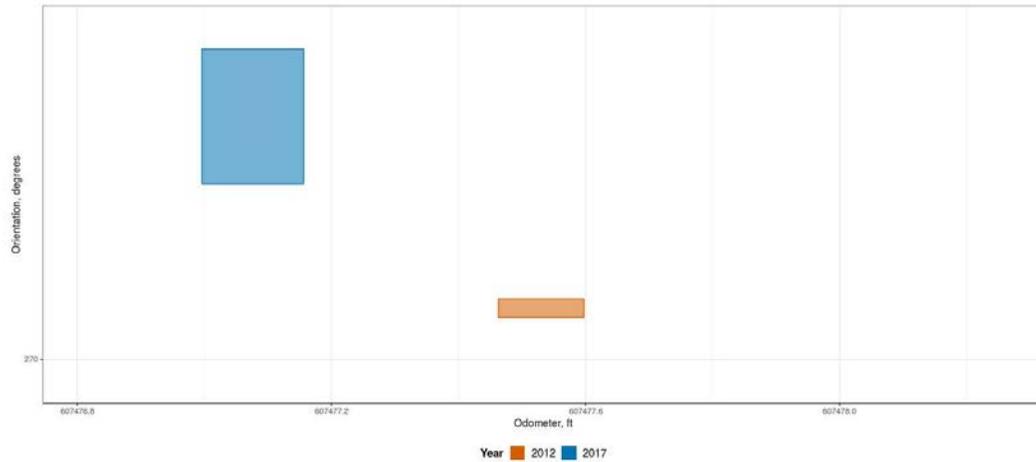


Figure 10: Zoomed plot without text shown (derived by brushing the above Figure 9 zoom plot).

With each zoomed selection, a data table containing information about the features is produced below the plot. Figure 11 presents information about the features in Figure 10. The user can choose which columns and how many entries to show. The user can also arrange the data in increasing/decreasing order and filter columns by certain attributes. The data table can then be exported in CSV or Excel formats.

ILI Year	Feature	Joint	Odometer	Orientation	Surface	Feature Type	Depth %
2012	1475	109320	607477.5	266.4	E	ML	13
2017	5576	109320	607477	251.4	E	ML	11

Figure 11: Data table based on data in zoomed plot in Figure 10.

A powerful option in BoxIt is the 3D image that uses the same data as in the 2D interactive plot but provides an elegant three-dimensional view of the pipe. The same portion of the pipe that was shown in 2D in Figure 8 is shown in 3D in Figure 12. Using the mouse, the user can rotate the pipe and zoom in. The user can also change which feature types and ILI years to display, as with the earlier 2D plots.

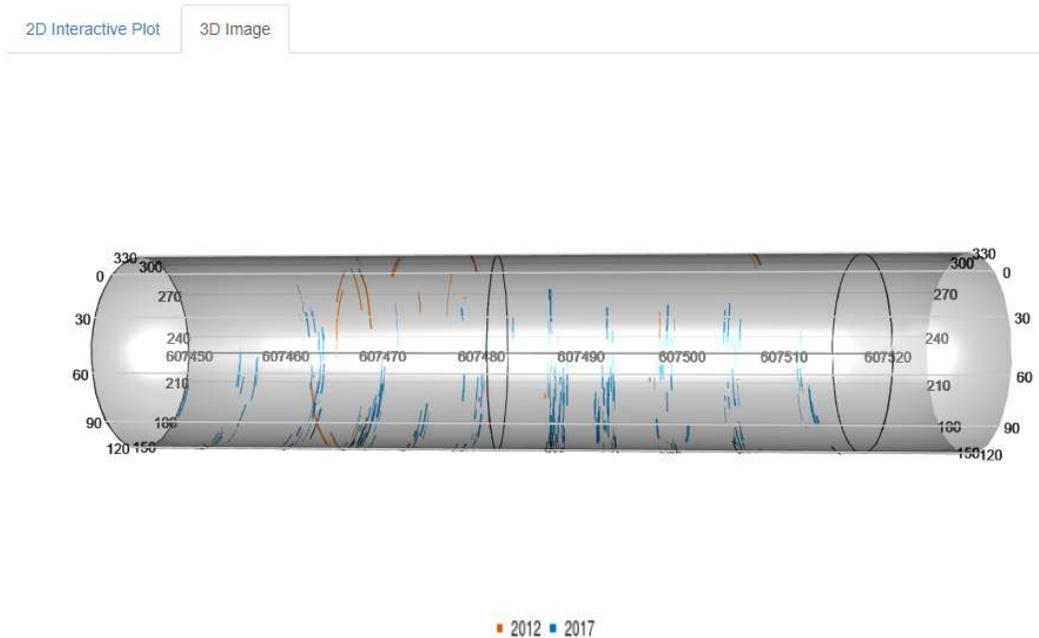


Figure 12: 3D pipe image using same data as in 2D plot from Figure 8.

3. BoxIt Future

BoxIt in its current form has been described in this paper. With the additional video and demo links provided earlier, the reader can obtain a reasonable understanding of the capabilities of BoxIt, especially if in-line inspection data for pipelines is not a new topic. DNV GL is in the process of putting BoxIt into the Veracity open industry digital platform (Veracity, 2019 [5]). BoxIt will initially be free world-wide. The next improvement to the app will include analytics, such as corrosion growth estimation, that is a high demand output. More recent DNV GL R based apps, such as CompScreen that screens every corrosion call in the most recent ILI run, may be integrated into BoxIt, as well as joint

alignment capabilities (AlignIt). The generation of html maps using a Leaflet map widget (Leaflet for R, 2016 [6]) provides the user interactive geospatial maps that fold in the overall assessment of the data and gives accessibility information for those locations most in need of further action. An API 1163 Shiny application has been created which allows for comparison of excavation dig data to the ILI estimates from the pigging runs. Although BoxIt is currently a visualization-only web application, future versions will incorporate these separate programs to provide the industry a useful tool for assessing pipeline integrity.

References

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