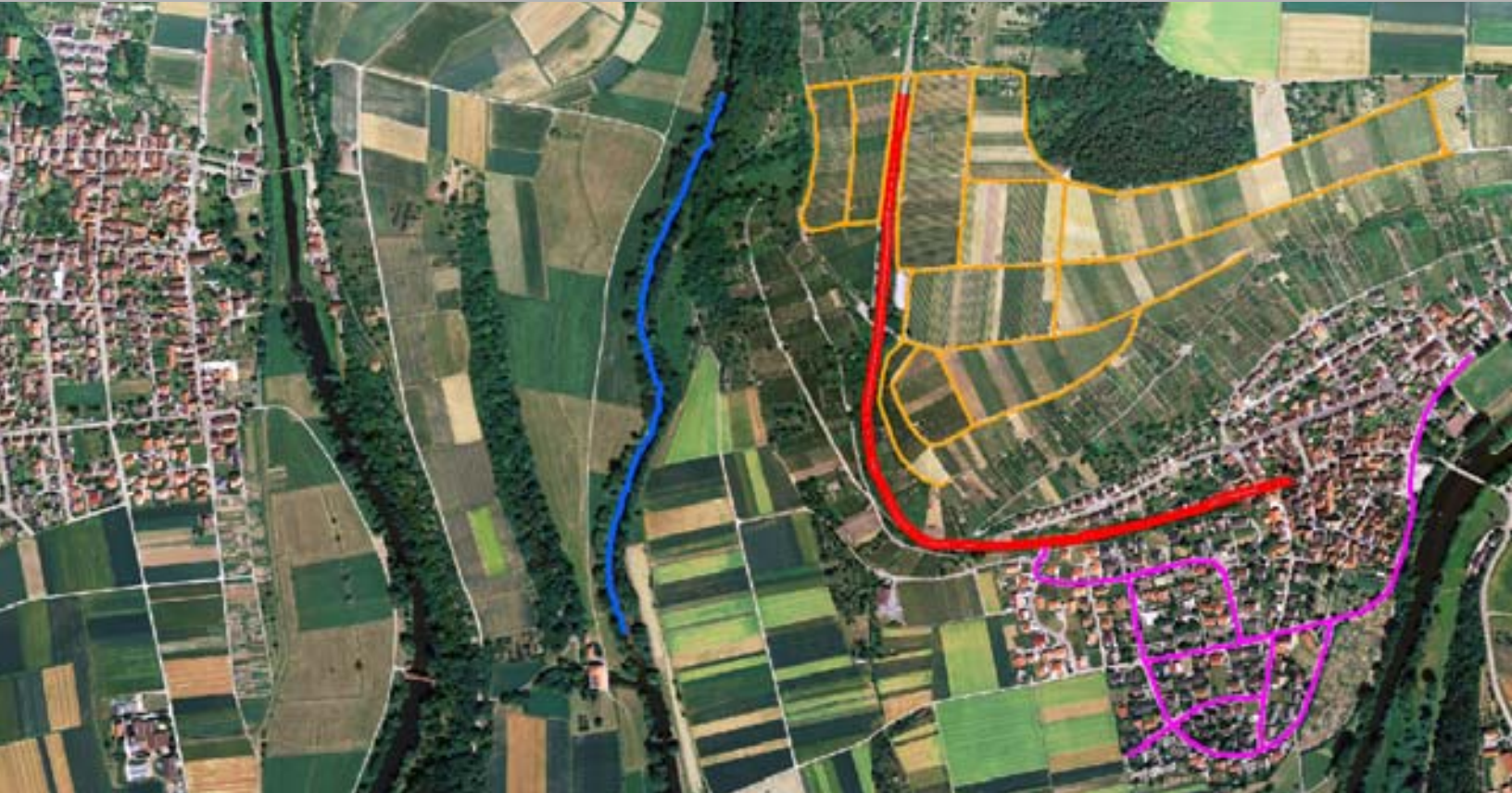


Extracting Features using **IMAGINE Easytrace™**

A Technical White Paper



- when it has to be right

Leica
Geosystems

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IMAGINE Easytrace™

■ Introduction

In the geospatial imaging industry feature extraction relies heavily on labor intensive digitizing. The heads-up digitizing method is used for collecting GIS-ready data from geospatial imagery. It is costly, time consuming, and tedious. To obtain object vector information from imagery, for example the shape of a lake, requires an operator to visually follow the curved boundary of the lake and digitize many points - this could be inaccurate and is certainly very time consuming. Fully automated feature extraction, one of the hottest issues in the industry, would greatly improve productivity and eliminate inefficient manual digitizing. However, due to the complexity of the problem, to date there are not any automatic systems that can extract features from imagery to automatically update vector data for GIS/Mapping while eliminating the need for post-editing or operator intervention. As a trade-off, semi-automatic feature extraction can relieve much of the manual labor, reducing the time consumed and cutting the cost.

Semiautomatic feature extraction fuses capabilities of computer and human operator. In a semiautomatic system, an operator identifies and locates the feature or object (this is the part that is extremely difficult for the computer to do). Once identified and defined by a few digitized points, the computer can finish digitizing the feature thus saving significant operator time.

A successful semiautomatic feature extraction system should be easy-to-use and provide instant result feed-back and undo capability. It should be able to extract features more accurately and much faster than pure manual digitizing.

IMAGINE Easytrace™ for higher productivity

In order to assist you in efficiently digitizing linear features from geospatial imagery, Leica Geosystems Geospatial Imaging offers a powerful add-on module - IMAGINE Easytrace™. The capabilities of this module are embedded in the IMAGINE Viewer, from which you can digitize any feature by Vector, AOI, or Annotation tools as well as load and display raster/vector data. Currently IMAGINE Easytrace™ focuses on tracing linear features, such as ribbon features (like roads and rivers) and object boundaries.

Main features of IMAGINE Easytrace™ are:

- Fast response - extraction results can be displayed in real time;
- Capable of processing any raster image displayed in the viewer;
- In most cases, no need for data pre-processing;
- Integrated with manual digitizing minimizes learning curve and makes it easy-to-use;

- Different tracing modes deliver high flexibility to different data type and image scene complexities;
- Hot keys enable you to quickly switch between various digitizing modes;

How IMAGINE Easytrace™ Works

The linear features that IMAGINE Easytrace™ currently operates on are:

- Ribbon features, IMAGINE Easytrace™ draws them by centerline or dual parallel lines
- Boundaries

Ribbon features are linear features that have a definite and nearly constant width and similar texture (or 'pattern') along the extension of the ribbon. Most roads, trails, and some rivers are considered ribbon features. The width of these features must be at least one screen pixel. Similar pattern on the ribbon means that it has consistent texture, which may be simply lighter or darker than the background, or more complicated things such as multiple lanes with lane markings on high resolution images. [Figure 1](#) shows typical ribbons that IMAGINE Easytrace™ can extract.

Boundaries are linear edge lines (can be straight or curved) on images. Boundaries reflect the discontinuity of intensity or color that usually separates different areas or objects. Typical boundary features are road edges, hydrologic object boundaries and boundaries separating different land uses.

Figure 1: Ribbon Features

Typical Ribbons (roads)



Road traced by IMAGINE Easytrace™



River traced by IMAGINE Easytrace™



What you see is what you get

Instead of directly using image source data, IMAGINE Easytrace™ deals with semiautomatic extraction based on the screen image in the IMAGINE Viewer. That means for any raster image, IMAGINE Easytrace™ uses at most three bands of data which is converted from image source data to red, blue, and green channels for display on the screen. IMAGINE Easytrace™ is an interactive tool guided by an operator who recognizes features from the screen image. If the features can be identified through the displayed image, the tool should be able to trace them, otherwise if you are unable to see a feature in the displayed image, it is unlikely that the tool could trace it.

The objects created by IMAGINE Easytrace™ may be edited by any of the IMAGINE Vector, AOI, or Annotation editing tools. It is important to note however that some layer types do not support both polygons and polylines.

Data types

IMAGINE Easytrace™ operates on the screen image so that typically it can process any image displayed in the Viewer.

Multi-spectral vs. panchromatic

Panchromatic images displayed on the screen are usually continuous tone grey scale images. As long as the contrast of the image is high enough or the features are clear and sharp enough, IMAGINE Easytrace™ will work.

Multi-spectral images are usually displayed on the screen as color images. Computer display systems use three color channels (bands) Red, Green and Blue for displaying images. Default processing in IMAGINE Easytrace™ is that it internally gets the image pixels from those displayed in the viewer window and averages the three bands (R,G and B) into one band. In some cases, the internal averaging could have negative influences and may need some image processing to get better performance; this is explained in [“IMAGINE Easytrace™ - Tips and Tricks” on page 9](#).

8 bit/16 bit/32 bit/float

The bit count of each pixel has little impact as long as the image data displayed in the viewer window is visually suitable for the operator to trace the features, otherwise additional pre-processing should be done before using IMAGINE Easytrace™.

Resolution and application areas of the image

Resolution, image content, and scene complexity always affect the performance of image processing software. Normally urban areas produce more complex image scenes while rural areas are relatively simple. Urban, suburban, rural, desert, mountain, etc. will have no greater impact on the performance of IMAGINE Easytrace™ than on any other interpretive package. In [“IMAGINE Easytrace™ - Tips and Tricks” on page 9](#) we will discuss some tips regarding how to use IMAGINE Easytrace™ in different image scenarios.

Workflow Inside the System

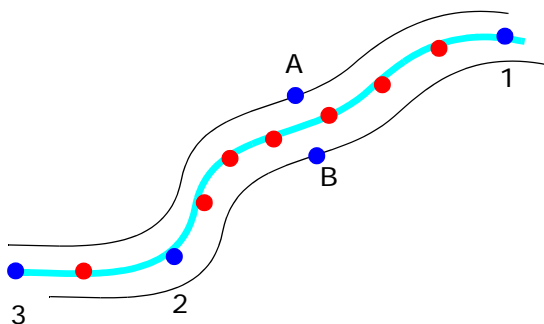
IMAGINE Easytrace™ works using feature extraction algorithms that try to find an 'optimal' result based on template matching and some internal search criteria.

For ribbon feature extraction, IMAGINE Easytrace™ uses the operator-specified template to perform extraction. The template is a small image window that indicates the ribbon pattern. Initially, you digitize one point on each edge of the ribbon to specify the template. See points A and B in [Figure 2](#). The two points should be as accurate as possible to indicate the edges of the ribbon so that the width and ribbon pattern will be good for subsequent processing. The system provides an option for you to reuse the template when you want to digitize groups of the same type ribbons. This is a common situation in road digitizing. In this case, you do not need to measure the template again. For boundary tracing, the algorithm uses default templates internally so you do not need to specify a template.

Next, the operator simply digitizes a start point and an intermediate (or end) point. See points 1 and 2 in [Figure 2](#).

Template matching attempts to match the template with the image along the search direction collecting candidate points of the feature. An optimal search algorithm is then applied to select a best route from the start point to the end point to fit the linear feature based on all possible candidate paths into which those candidate points fit well.

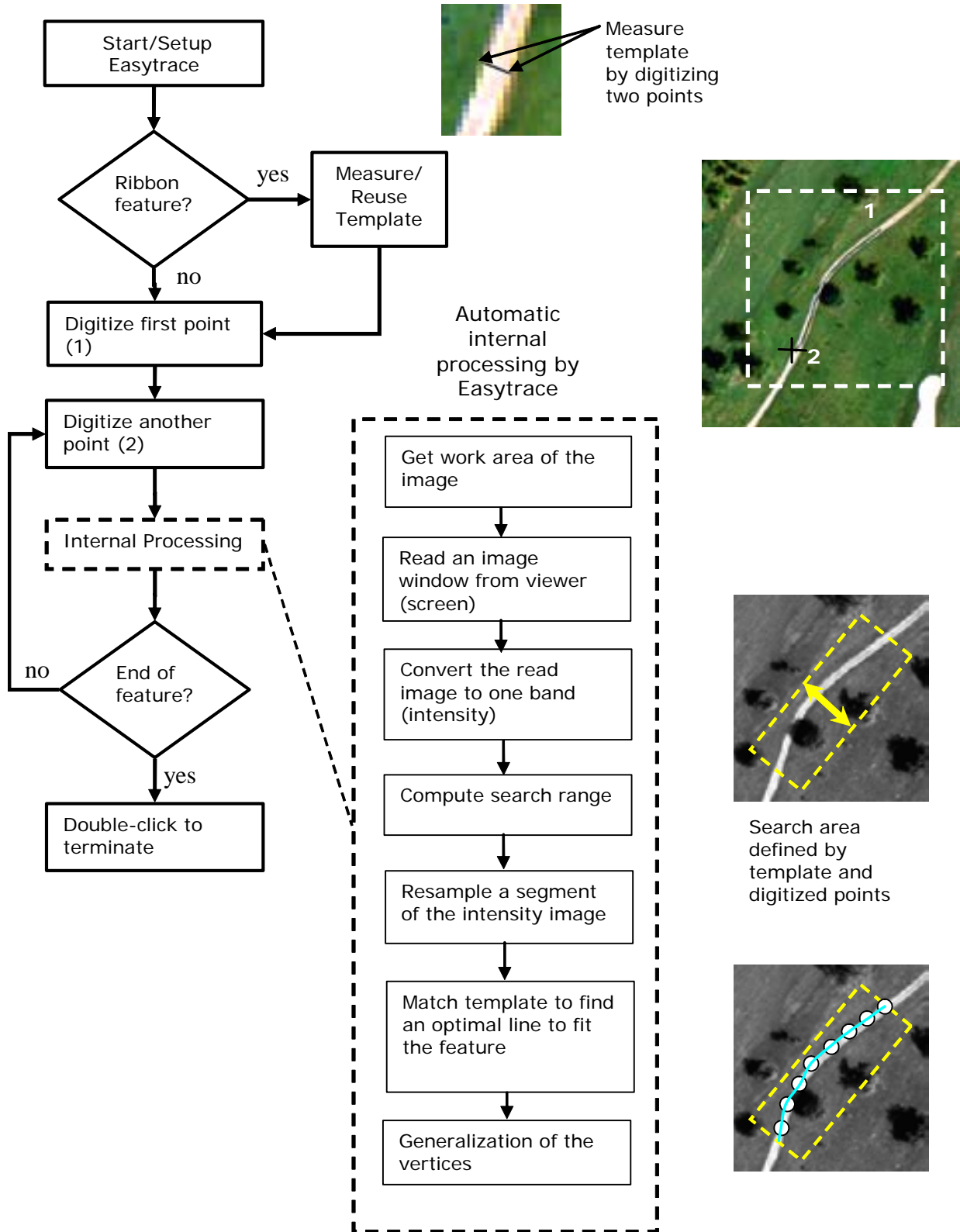
Figure 2: Digitizing Linear Features



IMAGINE Easytrace™ automatically adds points as necessary to generalize the linear feature (red points in [Figure 2](#)).

[Figure 3](#) provides a good overview of the external workflow as well as the internal processing.

Figure 3: IMAGINE Easytrace™ Workflow

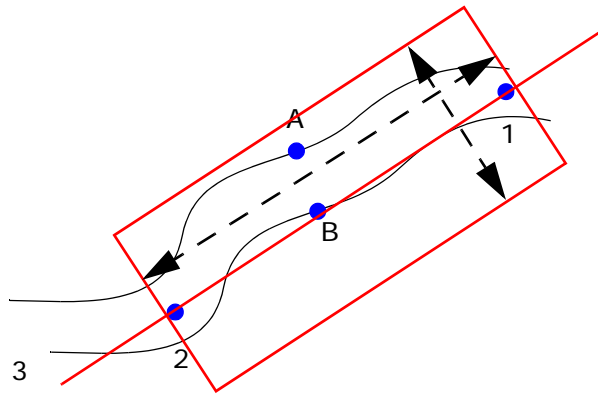


More About the Search Area

Understanding the search area is vital to successful use of IMAGINE Easytrace™.

The search area is defined in one dimension (search domain) by the seed points you digitized (1,2) and in the other (search range) by a complex algorithm that uses the template that you digitized (A,B). See [Figure 4](#).

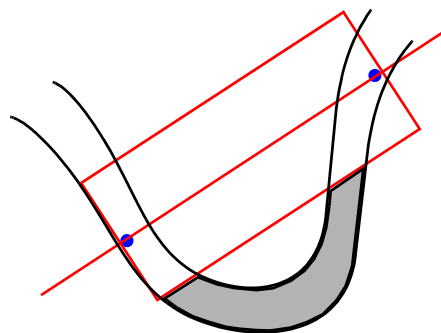
Figure 4: Definition of the Search Area



You can directly affect the search domain by changing the spacing between digitized seed points. Indirectly, you can alter the search range (favorably) by digitizing the template carefully at a location along the feature where the edges are well defined and free of obstructions like parked automobiles or trees.

The limiting effect of the search area works to reduce the amount of processing required to find your feature boundaries thus accelerating the operation. On the other hand, it can render features “invisible”. For example, in [Figure 5](#), the entire lower portion of the feature (shaded) is disregarded as the tool attempts to trace the ribbon between the digitized seed points. The addition of just one more seed point within the sharp bend will eliminate this problem.

Figure 5: Search Area Pitfall



■ Limitations of IMAGINE Easytrace™

Based upon the design and the algorithm implementation, there are several inherent limitations of IMAGINE Easytrace™ that you should keep in mind:

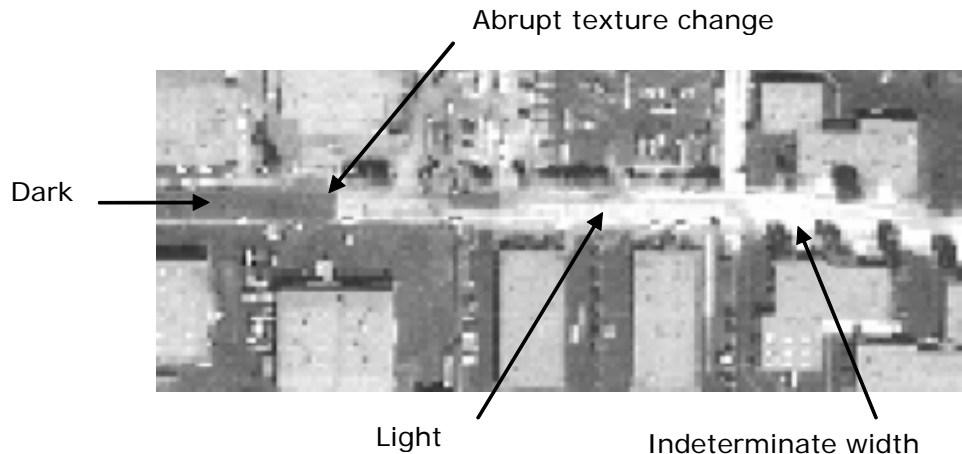
- Tracing features off screen so that the last seed point is not visible may produce unacceptable results since the algorithm only works on the image currently displayed in the viewer. Therefore when roaming, always keep the last added point within the view extent.
- In built-up areas on an image, the image scene is typically very complicated as shown in [Figure 6](#). Tracing ribbon or boundary features with IMAGINE Easytrace™ is as difficult as finding a feature's edges.

Figure 6: Built-up Area



- For digitizing ribbon features, if the width or texture of a ribbon varies drastically, IMAGINE Easytrace™ output may be unpredictable. See [Figure 7](#).

Figure 7: High-variance ribbon feature



- IMAGINE Easytrace™ can only trace the feature between the two points input by the operator. The two points define the search range (see the dashed yellow frame in the center right of [Figure 3](#)). IMAGINE Easytrace™ can not automatically trace the feature outside the search range. The purpose of using the search range is to trace the feature with high reliability (too big search range often results in unstable output).
- For multi spectral images, IMAGINE Easytrace™ may not properly trace the feature which is sharp enough to see on the screen. This is because, internally, IMAGINE Easytrace™ processes only intensity information of the displayed image. A big color difference may not be a big intensity difference. Experiment with the Color Band settings or perform image processing to enhance the image.
- For some highly convoluted features (such as rivers in small scale imagery) as shown in [Figure 8](#), you still need to digitize plenty of points.

Figure 8: Convoluted features





IMAGINE Easytrace™ - Tips and Tricks

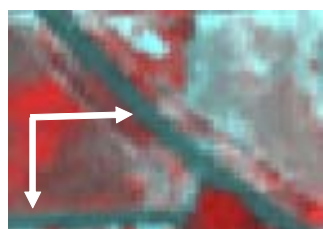
IMAGINE Easytrace™ is a semiautomatic system that is designed to combine the strengths of human vision and computer speed. For most images it helps to boost the efficiency and ease the operation in digitizing linear features. Just like any software, the better you understand how the software works in depth, the better you can take advantage of it. [“Workflow Inside the System” on page 4](#) has already presented the work flow and [“Limitations of IMAGINE Easytrace™” on page 7](#) has shown the limitations of IMAGINE Easytrace™. We hope these sections will help you to have a basic understanding and guide you in setting your expectations of the tool.

How much you can maximize the power of IMAGINE Easytrace™ depends on how much time you take to understand the tips & tricks and practice the tool. Using IMAGINE Easytrace™, the time saved in digitizing linear features varies depending on how complicated the image scene is and how familiar you are with the tool.

Proper pre-processing

If you feel the image is not clear or in good contrast to extract the features, you may need to do some pre-processing. The image processing can be simply adjusting the contrast, sharpening the image, filtering, or even classification that classifies the image pixels into different classes so that the boundaries of different features will be sharper. Many of these processes can be applied on the fly using tools available within the IMAGINE Viewer.

Figure 9: Color band selection for best performance



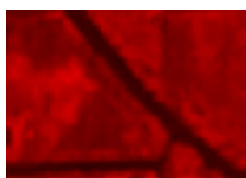
Road is clear in color image



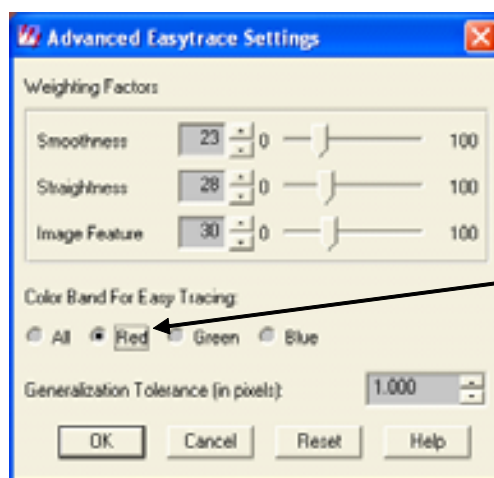
In the intensity image, it is difficult to visualize the feature



If you use the red band, the road feature is even sharper than in color image



Use band combination to display only red band



You keep the original display using RGB and set band used in Easytrace as Red. Easytrace will trace the feature based on Red band internally.

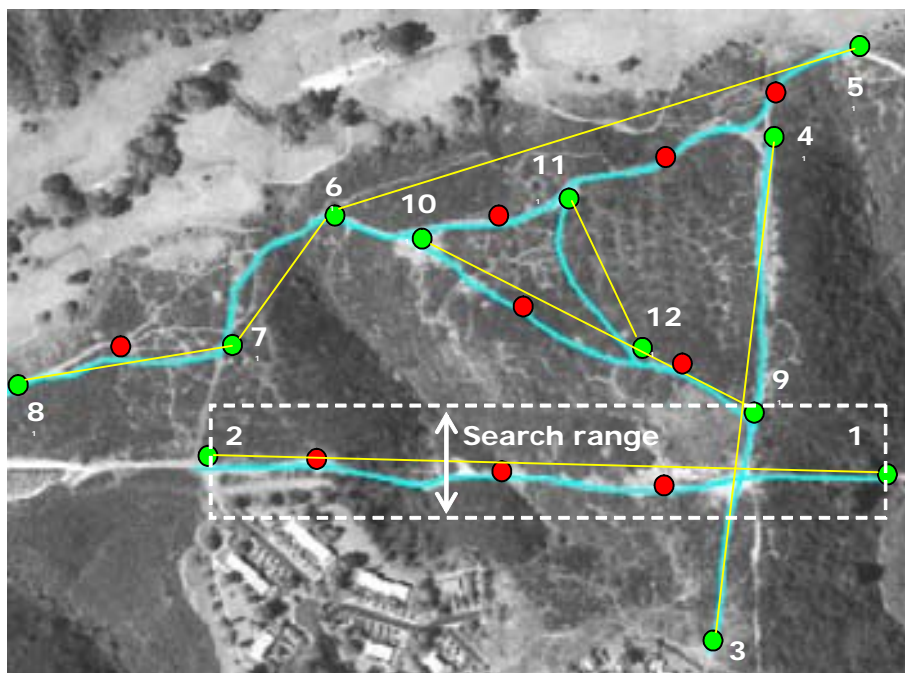
For multi-spectral imagery, sometimes converting RGB into one intensity band may not produce the best results. For instance, you may easily identify road features or boundaries on the screen by obvious color differences, but IMAGINE Easytrace™ fails to follow the feature shape. This most likely results from averaging the RGB value of each pixel which loses color information. Unfortunately the intensity of different objects are often nearly identical although their colors are different. If this is the case, you can determine the color channel (R, G, or B) in which the feature you intend to extract is in good contrast and change IMAGINE Easytrace™ settings to use only that channel. Or you can use the Band Combination tool to get a visually satisfactory displayed image. Especially for ribbon extraction, simpler ribbon texture and higher contrast between the ribbon and the background are much better. Figure 9 shows an example of how to get better results by setting the internally used color band.

Input seed points in good locations

Using IMAGINE Easytrace™, you need to input at least two points to extract a piece of line segment (can be straight or curved). We call the input points 'seed' points. IMAGINE Easytrace™ provides you with several tracing modes including discrete, rubber band, and streaming mode. Using discrete mode you digitize the seed points by clicking the mouse button. Using rubber band or streaming mode the position of seed points is automatically recorded as the cursor is moved. When in streaming mode, one seed point is recorded each time the cursor is moved approximately 20 screen pixels. Practicing and knowing how IMAGINE Easytrace™ works can help you input the seed points properly and make your use of the tool more efficient. Below are some typical situations and corresponding tips & tricks.

- For long and straight linear features (for example, street grid in urban areas), there is no advantage to using IMAGINE Easytrace™ since only two clicks can well define the feature and IMAGINE Easytrace™ may give a little curved result due to snapping to some local features which interfere with straight line extraction.
- Input seed points that can always construct the right search range (please refer to [Figure 3 on page 5](#)) in which the feature can be captured. [Figure 10](#), and [Figure 11](#) exhibit some typical cases that help you judge how to properly place the seed points.

Figure 10: Proper seed points - Example 1



Green points (light grey in B&W reproduction) are manually input points and blue lines are automatically traced by IMAGINE Easytrace™. When tracing features in simpler scenes (like in rural area), you can drag the rubber band further to save 'clicks'. For example, in this figure instead of digitizing additional points (for instance, the red ones in the figure), you can just input two points to extract the feature in the search range (the dashed white frame illustrates a search range). However, you should still input seed points at sharp corners of the curved feature (like at points 6 and 7).

In the illustration above, a total of 14 points (including two to measure the template) were input by the operator using IMAGINE Easytrace™; 81 points were automatically generated to trace the centerlines. This means 85% of the points are automatically digitized.

Figure 11: Proper seed points - Example 2

Correct

Incorrect



Green and black points are input using IMAGINE Easytrace™. Red lines are automatically traced lines. You should input seed points at corners of the feature otherwise IMAGINE Easytrace™ may fail to trace the feature properly. Comparing the left figure and the figure on the right, IMAGINE Easytrace™ can work properly when placing seed points at the corner spots.

Advanced Settings

Weighting Factors

The Advanced Settings dialog provides access to the Weighting Factors. Weighting factors are parameters used by the IMAGINE Easytrace™ algorithm to determine where the automatically generated points are located.

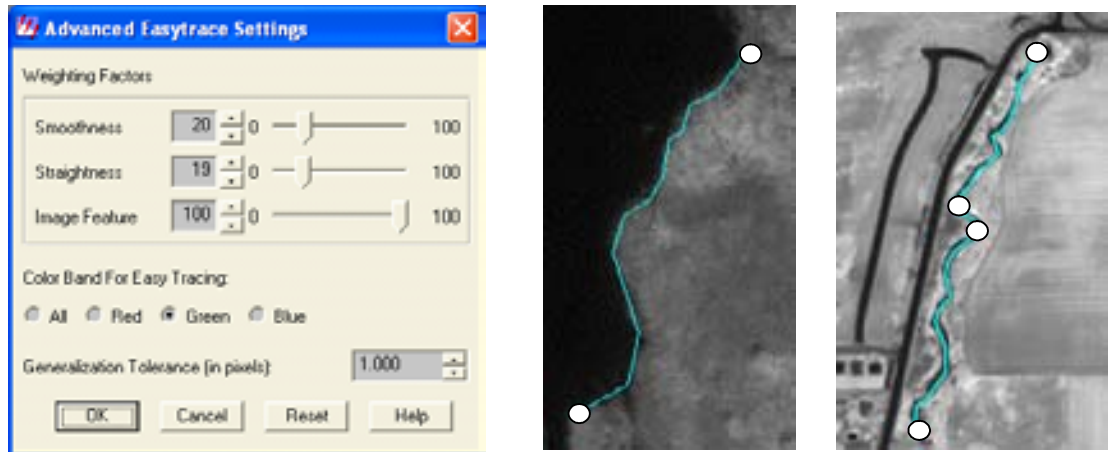
The weighting factors are:

- Smoothness - if you increase this value and the straightness and image feature remain the same, then more emphasis is placed on the smoothness of your digitizing results.
- Straightness - if you increase this value and the smoothness and image feature remain the same, more emphasis is placed on the straightness of your digitizing results.
- Image Feature - if you increase the image feature weighting factor and decrease the weighting factor of smoothness and straightness, then your digitizing results will more closely follow the image feature.

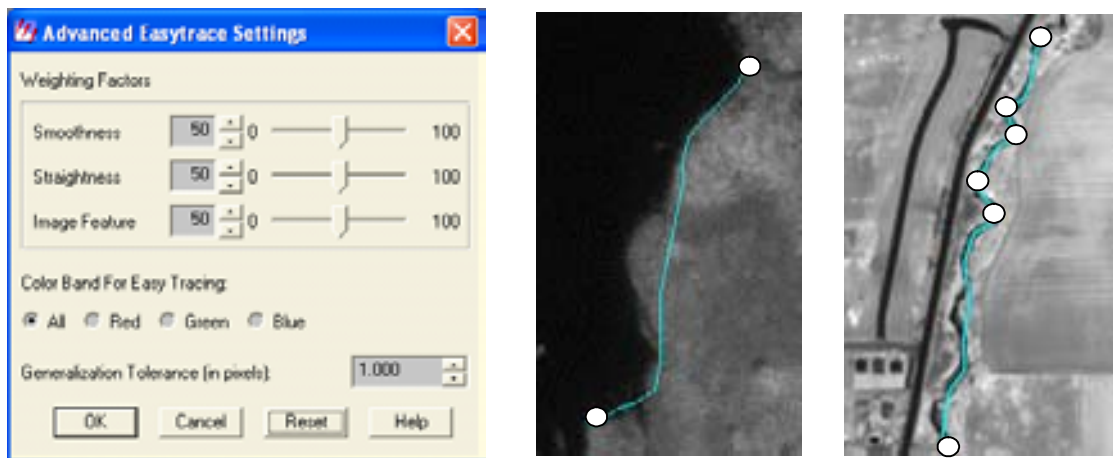
Weighting factors are all relative, for instance smoothness 1, straightness 1, and image feature 1, would give you the same results as smoothness 15, straightness 15, and image feature 15.

When digitizing natural features you may want your digitizing results to follow the image feature as closely as possible. In this case, increasing the image feature weighting factor and decreasing the weighting factors of smoothness and straightness may improve correlation of automatically generated points with the irregular boundary or ribbon. See [Figure 12](#).

Figure 12: Effect of higher image weight



Setting the image weight much higher than the other two can help to trace the curved features with fewer input seed points.



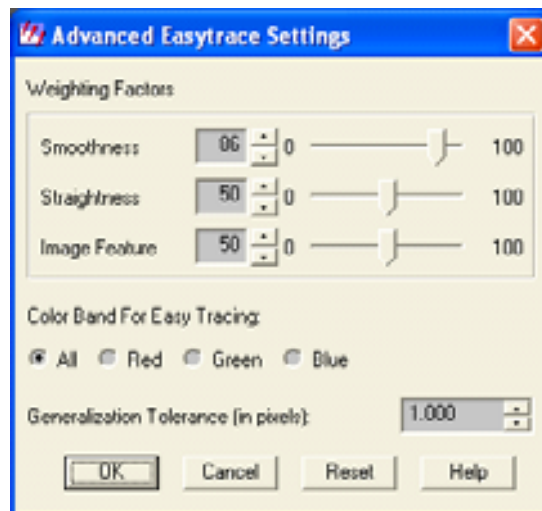
Using default settings for tracing curved features may require more digitized points to achieve the desired result.

When digitizing man-made linear features, such as roads, you can often count on relatively straight lines and smooth curves. In this case, increasing the straightness and smoothness weighting factor and decreasing the image feature weighting factor may improve correlation of automatically generated points with regular boundaries. See [Figure 13](#).

Figure 13: Higher smoothness weight



Output line is in the center of the ribbon, but it is not as smooth as you may wish



Setting the smoothness weight higher can help to trace the road features with smoother output.

Generalization Tolerance

Generalization Tolerance determines how many points are automatically generated. A larger value produces fewer points.

If you want your digitizing result to follow the image feature closely, then use 0 (to turn off generalization) or a small number for this parameter. The default value is 1.0; the maximum is 100.

Using hot keys to switch tracing modes

IMAGINE Easytrace™ provides four tracing modes when tracing a linear feature - manual, discrete, rubber band, and streaming. The following sections explain these modes in more detail.

You can choose any mode to start tracing the feature by setting the IMAGINE Easytrace™ setting dialog. When you are digitizing (before finishing one line) you can switch the tracing mode to any other modes by just pressing a 'hot' key. Using hot keys to switch the tracing modes makes the tracing more efficient. [Table 1](#) shows the assignment of the hot keys on the keyboard.

Table 1: Hotkey Assignment

Key	Function
R	Roaming
A	rubber bAnd mode
S	Streaming mode
D	Discrete mode
Shift	manual mode
Z	undo
C	Close polygon preview

Tips on using hot keys:

Put your left hand fingers on the hot key area when digitizing. The distribution of the hot keys is designed so that you can easily switch tracing modes, roam image, or undo. Properly using the hot keys is important for you to maximize the advantage of IMAGINE Easytrace™. Particularly for some complicated images you may need to use the hot keys frequently in order to obtain highest efficiency from IMAGINE Easytrace™.

- **Using Rubber band mode** (Hotkey 'A'). See [Table 2](#).

Table 2: Using Rubber band Mode

Description	When to use	Weaknesses
When moving the cursor, the position of the cursor is automatically used as the new input seed point and the tracing result is displayed instantly when the cursor is at a new position.	Rubber band is set as the default trace mode because it helps you monitor the trace in real time and allows you to click to record the result when you find a good fit to the extracted feature.	Displaying the rubber bands when moving the cursor may flash the display. When dragging a long line or digitizing a ribbon with large width (for example bigger than 50 pixels), the response could be slow.

- **Using discrete mode** (Hotkey 'D'). See [Table 3](#).

Table 3: Using Discrete Mode

Description	When to use	Weaknesses
Only when the left mouse button is clicked is the position of the cursor recorded as the new input seed point and the tracing result is displayed.	If the image scene is simple, the image contrast is good and the feature is sharp and simple, you know the result will be correct. Using discrete mode can reduce time compared with monitoring the flashing rubber band. An example is shown in Figure 14 .	No instant feed back about the tracing result. In some situations, the clicked new seed point results in incorrect or inaccurate output. This can lead to more undo actions and so limit the efficiency of IMAGINE Easytrace™.

Figure 14: Discrete Mode Operation



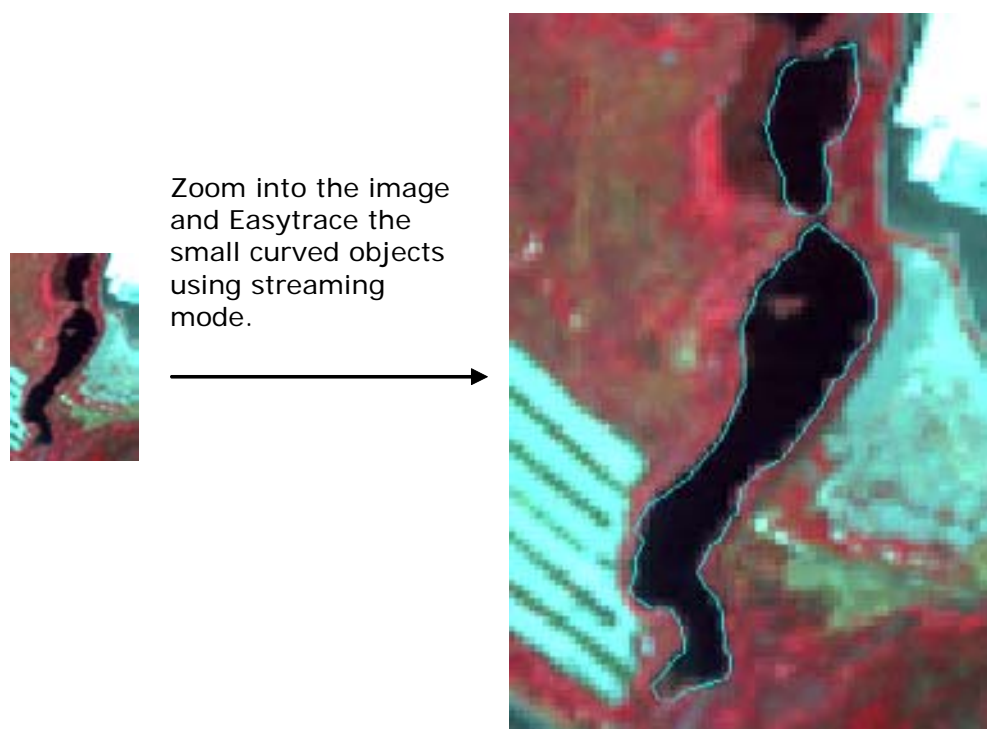
A total of 22 clicks are made using discrete mode, 145 vertices are automatically generated by IMAGINE Easytrace™. This means that IMAGINE Easytrace™ is increasing your productivity by a factor of seven.

- **Using streaming mode** (Hotkey 'S' - only valid in tracing boundary). See [Table 4](#).

Table 4: Using Streaming Mode

Description	When to use	Weaknesses
When moving the mouse, the position of the cursor is automatically recorded as a new digitized point (about every 20 pixels of travel) and the tracing result is displayed.	It is suitable for tracing very convoluted boundaries and small objects, see an example shown in Figure 15 .	You must move the cursor along the boundary more carefully since the search range is limited to about 20 pixels.

Figure 15: Using Streaming Mode



- **Using manual mode** (Hotkey SHIFT). See [Table 5](#).

Table 5: Using manual mode

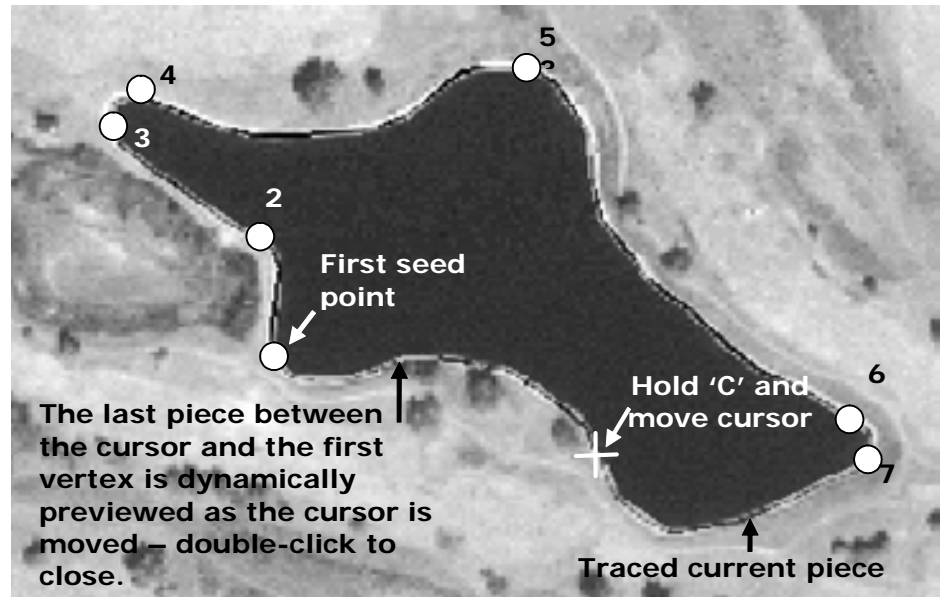
Description	When to use	Weaknesses
System records the clicked position and adds it into the vertices list describing the linear feature. It is identical to classic digitizing.	If the linear features are straight and very long this is the mode to use. Also, when tracing features in complicated scenes (heavy noises and occlusions etc.), switch to manual mode.	No extraction is carried out (no vertices can be automatically generated). The efficiency is as low as pure manual digitizing.

- **Close polygon** (Press and hold 'C') See [Table 6](#).

Table 6: Easy close polygon

Description	When to use	Weaknesses
When digitizing polygons using rubber band mode, if you are ready to close the polygon, press and hold 'C'. The tracing result of the last piece is displayed and dynamically updated as the cursor is moved. Double-click when ready to close. This saves time digitizing the last piece of the polygon. See Figure 16 .	See description.	

Figure 16: Easy close polygon



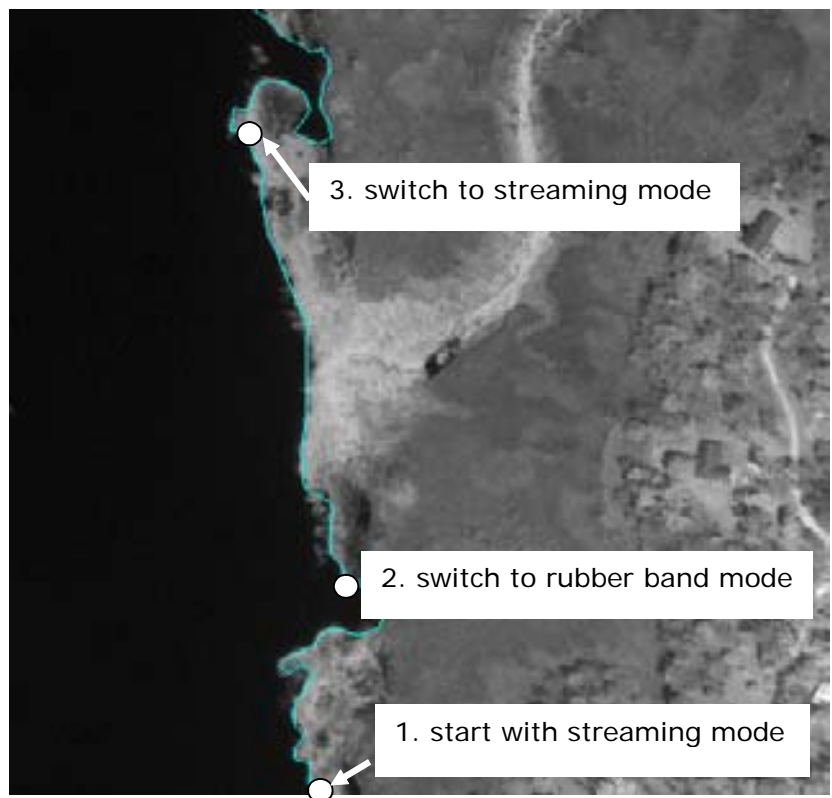
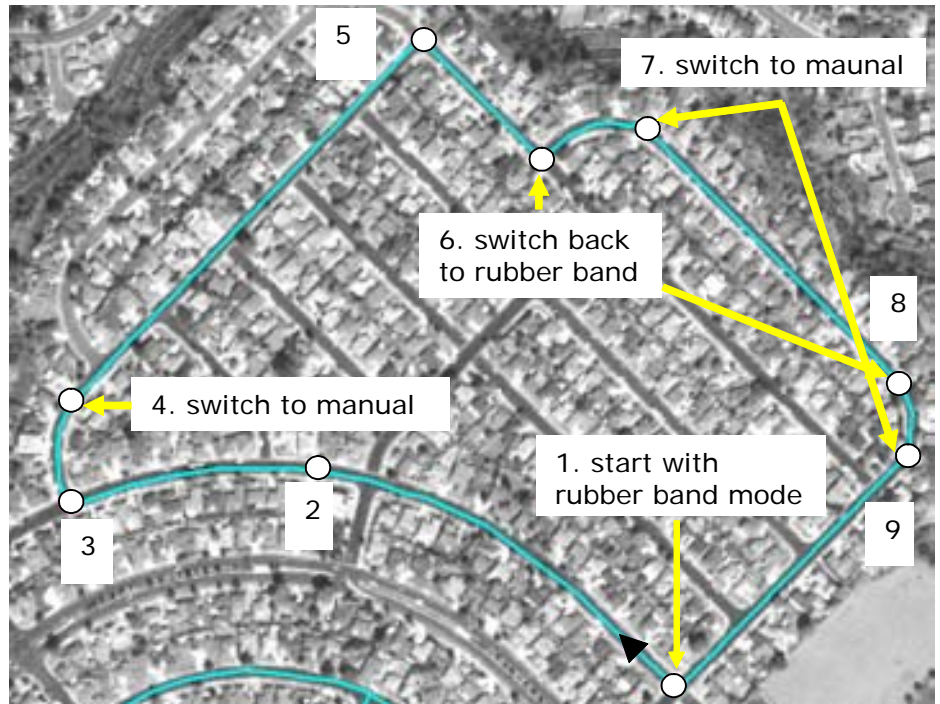
In the example above, the operator digitized 8 points using IMAGINE Easytrace™. Another 41 vertices were automatically generated (after line generalization with tolerance set at 1 screen pixel).

- **Roaming image when digitizing** (Hotkey 'R'). If you press 'R', the IMAGINE Easytrace™ mode will be automatically switched to Roaming mode. Pressing 'R' again stops roaming but switches trace mode to Manual. Remember to switch the mode by pressing one of the other hot keys.
- **Undo** (Hotkey 'Z' or 'BACKSPACE'). If you press 'Z', the system automatically deletes the last traced line segment. Pressing repeatedly or holding the Undo hotkey will step backward through the digitized points deleting them in reverse order. When in streaming mode you should switch back to manual or discrete mode first so that you are able to reposition the cursor to the last correctly digitized point without capturing more unwanted points.

Using hot keys

See the examples shown in [Figure 17](#). Properly using the right tracing mode will make the result better in correctness, smoothness, and accuracy as well as improve the efficiency.

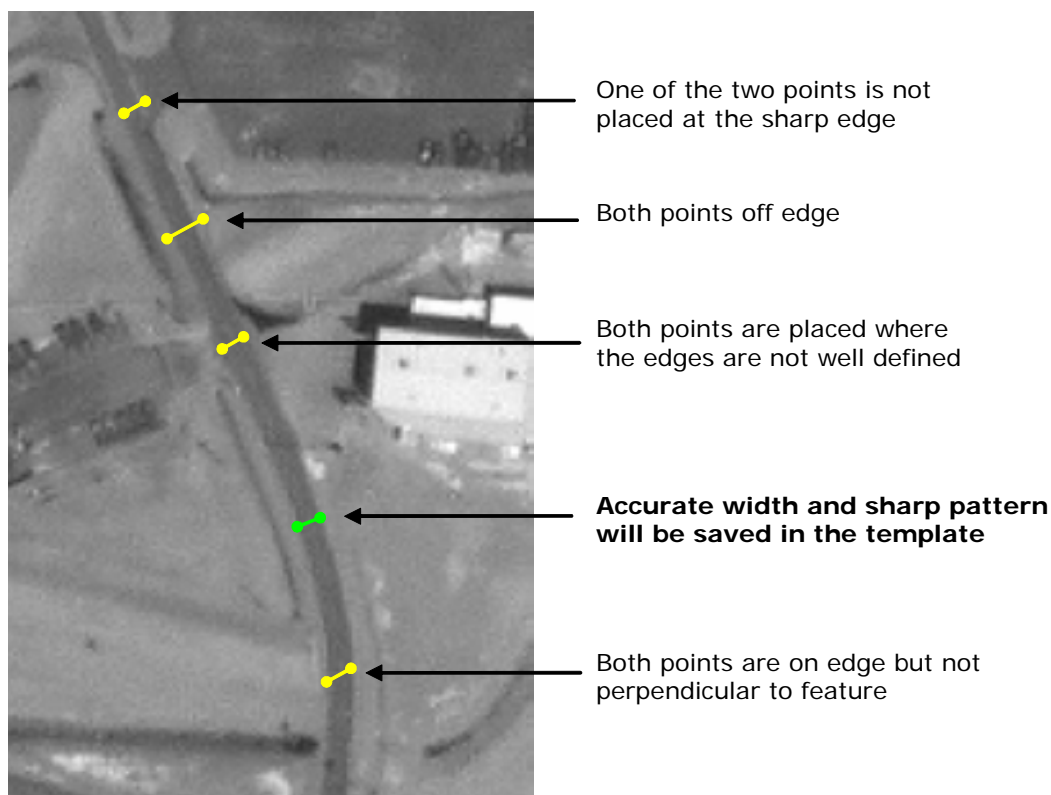
Figure 17: Mode-switching examples



Measure and Reuse Template

IMAGINE Easytrace™ algorithms are based on template matching. For digitizing ribbon features, you should measure or specify the template. [Figure 18](#) illustrates four ways to set a bad template. Only by digitizing two points on the clear ribbon edge can you be assured of an accurate ribbon width template. Although IMAGINE Easytrace™ can slightly and automatically adjust the template if you place the two points at the edge position inaccurately, we recommend you carefully digitize the two points as illustrated in the figure below.

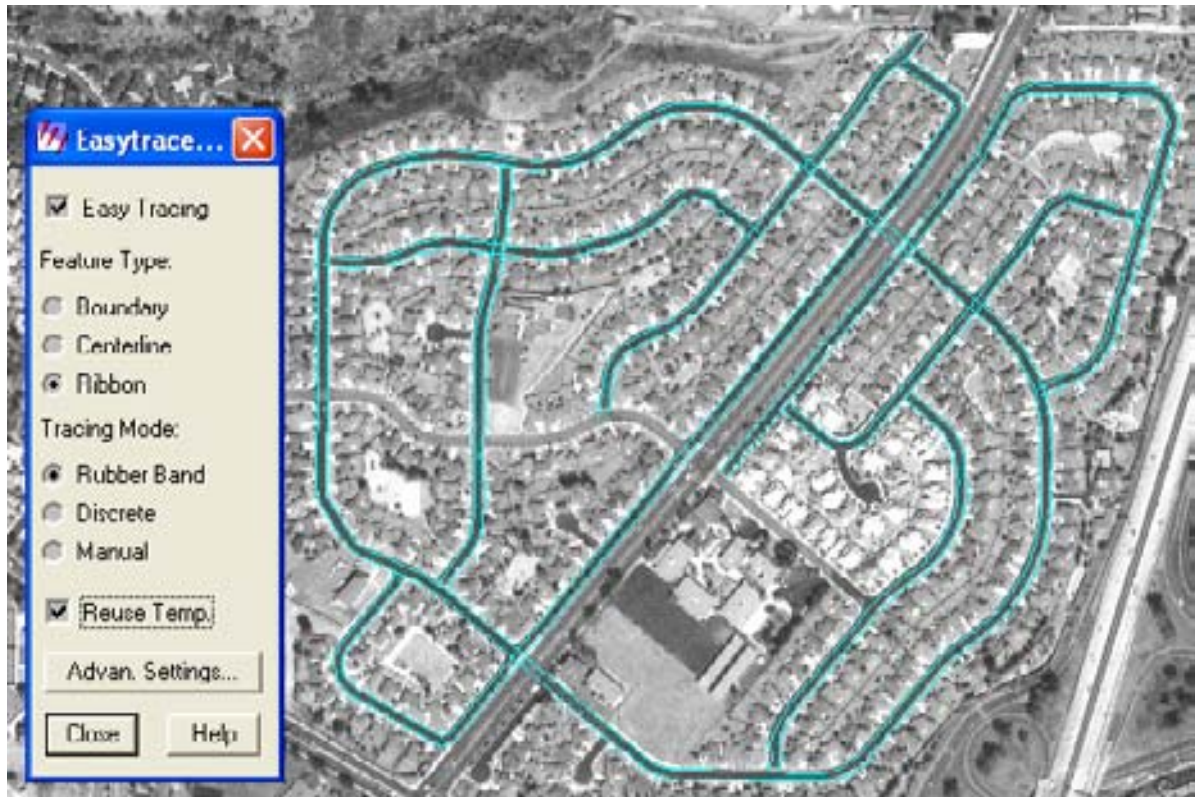
Figure 18: Template Construction



Other tips are:

- When digitizing narrow ribbons, you can zoom in the image to measure the template easily and more accurately. You can digitize at different zoom levels because the template is automatically resized when the image is zoomed. When digitizing, you must use the right mouse button to access the Quick View menu from which you can select an appropriate zoom level.
- In an area where there exists many ribbon features with the same width and pattern, you can carefully measure a template and digitize a ribbon, then check the 'Reuse template' check-box. Thereafter you can directly digitize similar ribbons (as centerline or ribbon) without digitizing two points to measure the template again. See an example shown in [Figure 19](#).

Figure 19: Reusing the template

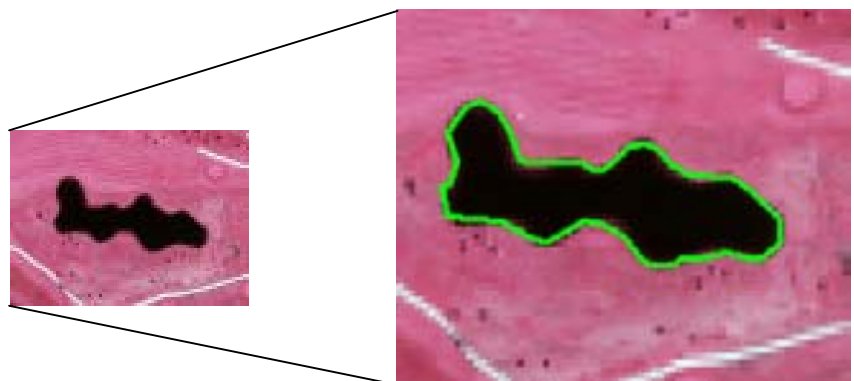


In the example above, 39 points were digitized by the operator using IMAGINE Easytrace™, 188 vertices are automatically generated (after line generalization with tolerance set at 1.0 pixel) - this is nearly an 83% improvement in performance.

Zoom the image and trace

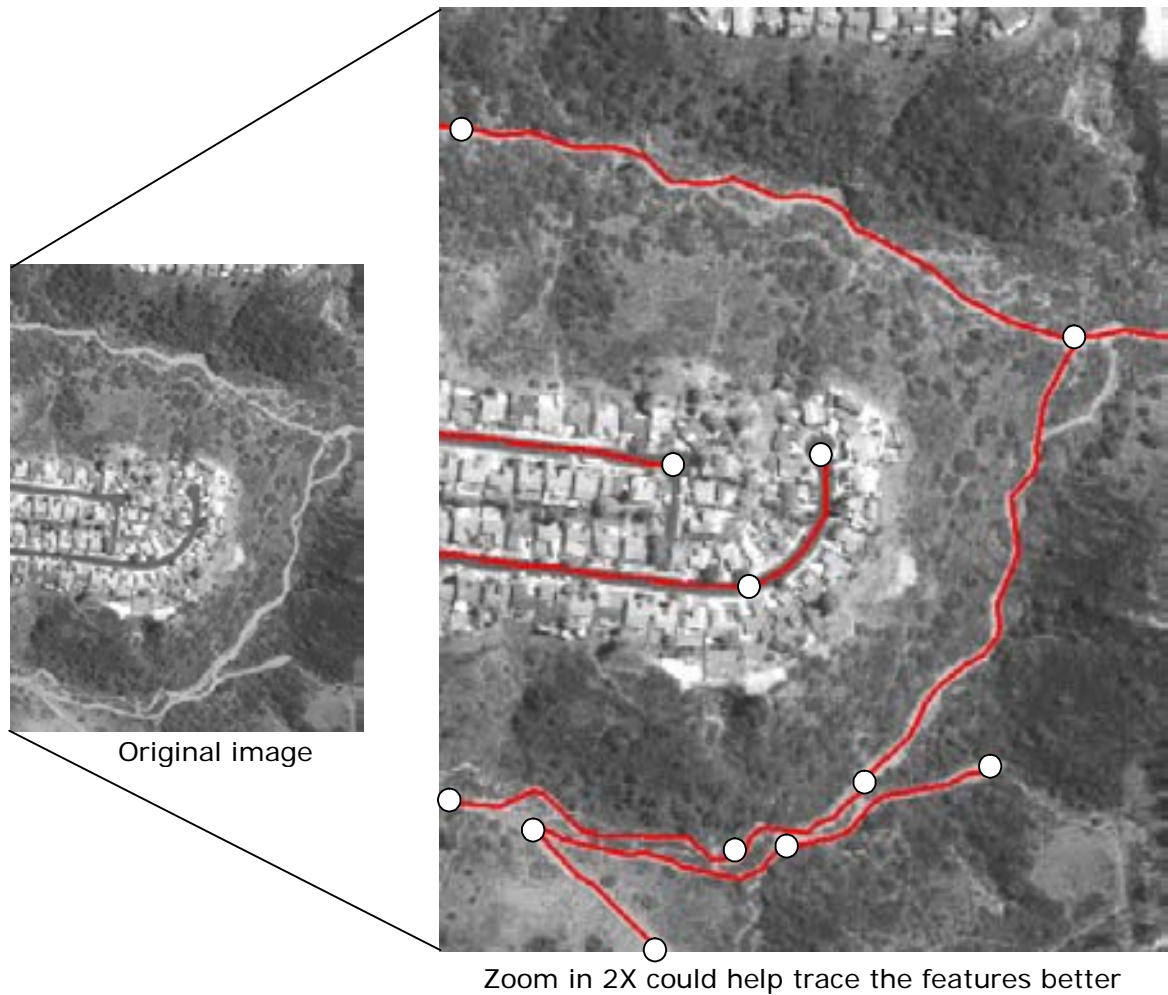
- For small objects, you can zoom in the image to get a more detailed shape of the object. Refer to [Figure 20](#).

Figure 20: Tracing small features



- Testing shows that tracing ribbons with widths of about 8-20 screen pixels gives the best performance in speed, correctness, and accuracy. So if the ribbon displayed is too narrow (like 1-3 pixels) or too wide (for example > 50 pixels), you can zoom the image into a proper level and then trace. See an example in [Figure 21](#).

Figure 21: Tracing narrow ribbons



Troubleshooting

In previous sections users can find the tips and tricks about using the tool. In summary, we recommend checking the following items:

- Select right feature type (boundary, centerline, or ribbon).
- If the output is not as smooth or curved as you would expect, check out the weighting factors in the advanced setting dialog and reset them if necessary. See ["Advanced Settings" on page 13](#)
- If you are collecting ribbon features and the output is obviously wrong under excellent image conditions, you might have measured or specified an incorrect template. Re-measure the template (at proper zoom level if necessary).
- If it is a color image (displayed in the IMAGINE Viewer), consider band processing as described in ["Proper pre-processing" on page 9](#).
- If the image contrast is low and features are hard to identify, consider some image processing to get the image visually better to be used for digitizing.
- Do not continue using IMAGINE Easytrace™ modes (streaming, rubber band, and discrete) when the output always fails to fit the feature you are intending to trace. Especially in noisy areas and complicated scenes, switch to manual and go through the difficult area. You can switch back to the IMAGINE Easytrace™ modes when you are clear of the congestion. You can even start with manual mode and switch to the IMAGINE Easytrace™ modes when you find it is appropriate. Use two fingers on 'SHIFT' (manual) and 'A' (rubber band) as they may be frequently used when tracing through varying image areas.
- Input 'good' seed points as described in ["Input seed points in good locations" on page 11](#).
- Place the seed points as close as possible to the feature (for ribbons, place them at the center of the ribbon). This will help reduce unwanted zig-zag between digitized points.
- If you are dragging a long line and the output looks wrong, re-input the seed point closer to the previous one, usually the output will be better when the search range is reduced.
- If you make the previous seed point out of the viewer window (unseen on the screen), IMAGINE Easytrace™ will most likely fail to extract the feature correctly, refer to ["Limitations of IMAGINE Easytrace™" on page 7](#). Mostly this happens when roaming the image, so be careful with this.

