RapidCorrelator™ v1.0

Technical Brief

May 2006

XStream™ Engineering

Contents

What is RapidCorrelator?

RapidCorrelator v1.0 is XStream Engineering's advanced Image Correlation and Deformation Analysis Technology. It offers full-field, multi-scale image correlation analysis for non-destructive, non-contact deformation, strain measurement and testing. The software also provides rich-media object annotation capabilities (text, audio, video, graphics, draw tools) to explain/document various artifacts within the applied analysis.

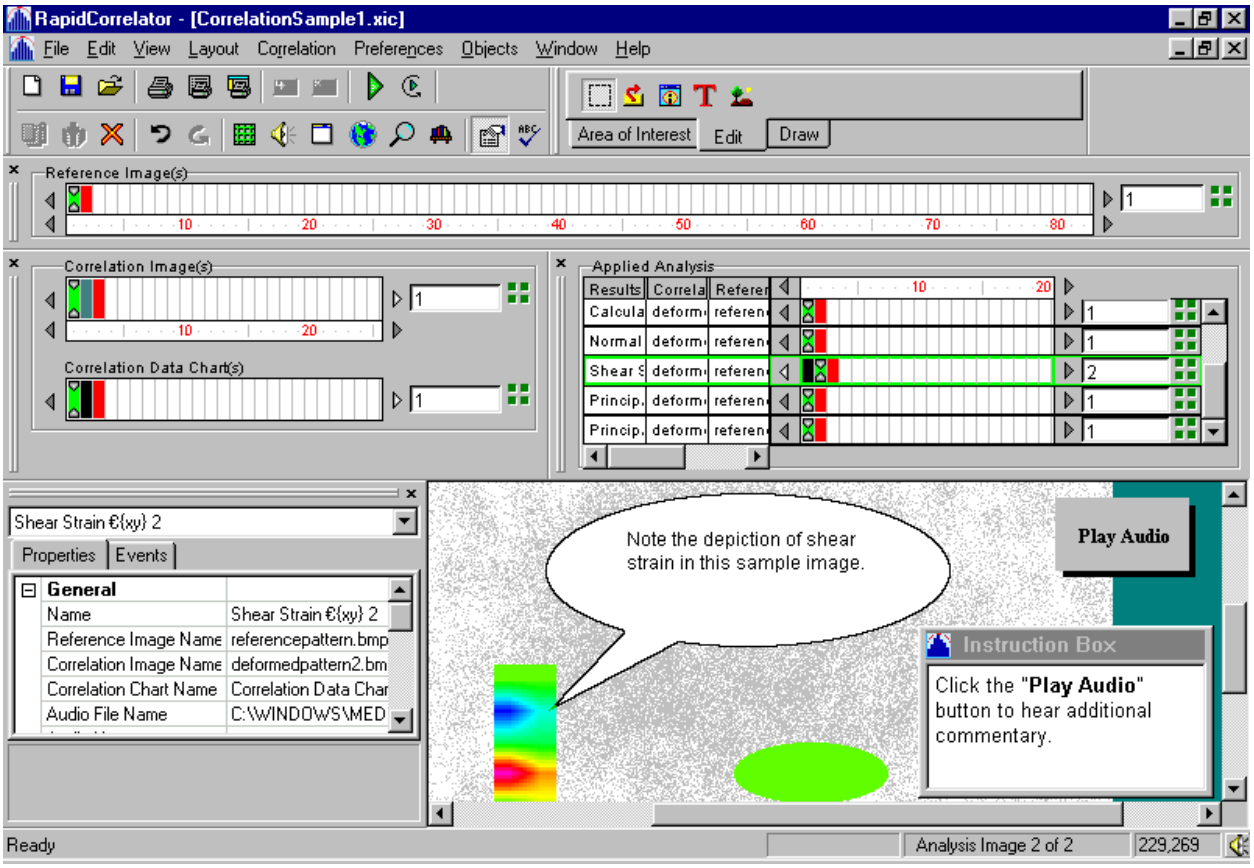

Figure 1: RapidCorrelator Interface

Image correlation is a technique based on surface analysis methods. These methods involve monitoring and identifying changes in a pattern applied to the surface of objects under observation, which have been subjected to some form of mechanical pressure or strain. Typically, images of the surface before and after deformation are sourced from a camera, microscope, scanning electron microscope (SEM), and/or atomic force microscope (AFM).

RapidCorrelator is used to automatically correlate and analyze these optical image sets to extract deformation profiles from tiny changes in the images. The original reference (undeformed) image and successive deformed images are imported into RapidCorrelator. Using special drag-and-drop tools, the user may easily select/identify one or more relevant areas of interest (AOIs) within the reference image (i.e., small regions of the image to which the analysis will be restricted). After specifying the AOI(s), the user can initiate the automated correlation calculation process at the click of a button. The system automatically analyzes the AOIs within the images and calculates precise measurements of surface deformation, displacement, gradient levels, and strain.

Once the correlation calculation process is complete, the generated results for each deformed image are presented in a corresponding correlation data chart for easy viewing. In addition, the correlation data values for each deformed image can be represented graphically as applied analysis frames. These are

visual contour maps used to illustrate and reveal displacements, strains, etc. They can be browsed, viewed, and played back by the user.

RapidCorrelator provides a multimedia editing suite of drag-and-drop objects and drawing tools that enable the user to create and edit different types of annotations on images and applied analysis frames. Annotations can be in the form of text, audio, video, graphics, lines, and shapes. They are extremely useful for enhancing the presentation of the images and explaining/highlighting different artifacts within the analytical results.

RapidCorrelator includes a built-in image player that facilitates timeline-based, animated playback of image deformations for effective visual communication of analytical results. Any selected set of deformed images or applied analysis frames can be played once or in a continuous loop, which enables the user to see the progression of the deformation from one image to the next and view the dynamics of the strains, loads, displacements, etc. The user may also customize the playback of the images by adding hyperlinks (to facilitate non-linear navigation between different images) and specifying transition time delays between different images.

RapidCorrelator also enables users to publish correlation data to Microsoft Excel (XLS) format and provides capabilities for printing image sets to paper.

RapidCorrelator System Requirements

The requirements for installing and using RapidCorrelator include the following:

- Microsoft Windows 98, NT, 2000, 2003, ME, or XP
- Pentium 3 (or higher) processor
- Minimum 64 MB of RAM. (128 MB is recommended)
- Minimum 100-150 MB of free disk space
- Minimum 256 color support on the machine
- Windows Media Player 6.4 (or higher) – Required to support video and audio playback.
- Microsoft Excel 2000 (or higher) – Required to export correlation data to Excel (.XLS) format.
- Local or network printer – Required to print RapidCorrelator files to paper.

Basic Steps for Using RapidCorrelator

Correlating and analyzing surface images with RapidCorrelator involves a few simple steps. These include the following:

- Determine sample test
- Set up cameras and configure tool
- Run deformation test
- Collect sample images
- Run analysis
- Annotate, document experience
- Communicate results

Reference (Normal) Images and Correlation (Deformed) Images

Multiple reference and correlation images may be added to a single RapidCorrelator file.

A reference image is a normal (undeformed) image. A correlation image is a deformed version of the reference image in which some type of change or deformation exists.

Each reference image is associated with its own unique set of correlation images. For each individual reference image, the user may add multiple correlation images that will be correlated with the reference image. Up to 20 reference images may be added to a single file. For each reference image, the user may add up to 100 correlation images.

Surface images of all types (.BMP, .GIF, .JPEG, .PNG) may be imported into RapidCorrelator, including images sourced from a camera, microscope, SEM, and/or AFM (macro to nano-scale). RapidCorrelator supports 8-bit, 16-bit, 24-bit, and 32-bit images.

NOTE: Both the reference image and correlation images can be viewed in resizable, palette-style windows that are separate from the main workspace area. This enables the user to see the main reference image while simultaneously viewing, browsing, and editing the related correlation images, data charts, or applied analysis in the main workspace area. Similarly, the user can see the correlation image(s) while simultaneously viewing, browsing, and editing the related data charts or applied analysis in the main workspace area.

Area of Interest (AOI) Regions

An Area of Interest (AOI) is a selected region of the reference image to which the correlation calculations and analysis will be restricted. By dragging and dropping AOI objects onto specific areas of the reference image, the user may easily select/identify one or more areas of interest that will be correlated.

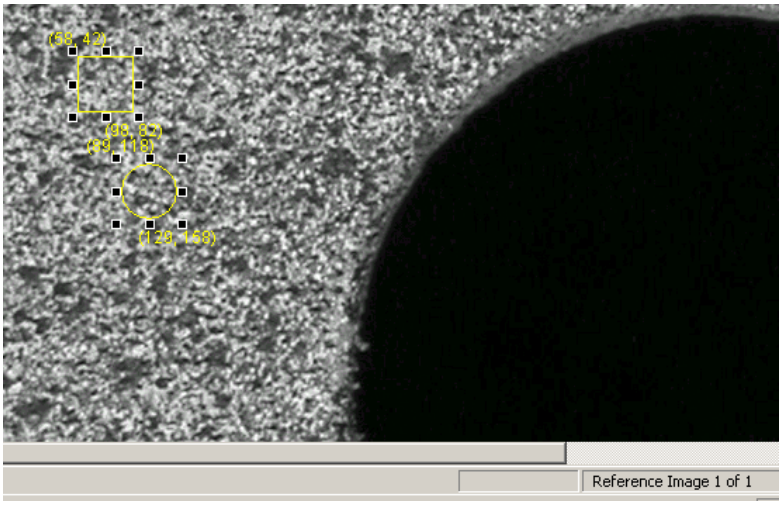

Figure 2: AOI Regions

As shown above, an area of interest within the reference image is identified by overlaying it with either a transparent rectangle shape or a transparent ellipse shape.

Input Parameters/Settings

Before calculating the image correlations, the user may configure a number of input parameters/settings to customize and optimize the process:

- **Excluding Images From Correlation** – Any reference image or correlation image may be either included in or excluded from correlation. The ability to temporarily exclude selected images from the correlation calculations enables the user to customize the output and increase the processing speed.
- **Search Settings** – The user may determine the search parameters for the correlation by configuring the following reference image properties:
  - ***Sub Image Size*** – Specifies the square area size (in pixels) of the subimage, which is a defined subset region of the area of interest (AOI). The AOI is divided into defined subset regions, which are the basic blocks on which correlation is performed. During correlation, the displacement and gradient values are determined for a single subimage and then interpolated for all subimages in the AOI so as to find the whole-field deformation profile.
  - ***Column Step*** – Specifies the column step (in pixels). The column step is the position on the y-axis where the subimages are placed during correlation.
  - ***Row Step*** – Specifies the row step (in pixels). The row step is the position on the x-axis where the subimages are placed during correlation.
  - ***Search Area (+/-)*** – Specifies the search length (in pixels). The search length is the area within which the search is done from the point of interest.
  - ***Precision*** – Specifies the decimal precision (i.e., the number of decimals) for the correlation output. Any value from 0 to 9 may be specified. A higher number of decimals will translate to more accurate displacement values.
- **Interpolation** – Interpolation is an imaging method to increase (or decrease) the number of pixels in an image. Interpolation is generally required to achieve optimal sub-pixel accuracy (since discrete points do not necessarily move in units of pixel spacing). The interpolation method used during correlation may be specified as one of the following:
  - ***Bilinear Method*** – This is the default option. It involves interpolating linearly along each row of the subimage, considering the closest 2x2 neighborhood of known pixel values surrounding the unknown pixel. It then takes a weighted average of these 4 pixels to arrive at its final interpolated value.
  - ***Bicubic Method*** – This method goes one step beyond bilinear by considering the closest 4x4 neighborhood of known pixels (for a total of 16 pixels). Since these are at various distances from the unknown pixel, closer pixels are given a higher weighting in the calculation.
- **Image Calibration** – In order to determine the scale factor for a given set of reference and correlation images (taken under a particular scenario), RapidCorrelator enables the user to display a customizable ruler in the workspace area. This enables the user to determine measurements for purposes of image calibration. Because there are many types of scientific and other measurement units that may be required, RapidCorrelator enables the user to customize the measurement unit/type that will be displayed on the ruler. By specifying reference points on the ruler, the user may define the size of a single unit on the ruler, and the user may also specify the number of pixels that will be present between the two reference points on the ruler.

Seed Points and Initial Guesses

In RapidCorrelator, **Seed Point** or **Initial Guess** settings are specified prior to correlation in order to narrow the search to a small area and obtain optimal correlation output.

If neither the seed point nor initial guess settings have been configured, the correlation will be performed on the entire subimage area. Specifying seed point or initial guess settings is especially useful when there is a large displacement in the x-axis or y-axis direction between the reference and correlation images.

The seed point/initial guess value is the estimated displacement/offset in terms of the number of pixels in the x and y directions respectively. The coarse search will be centered at the new location (Xnew=Xo+Uguess, Ynew=Yo+Vguess) and search the neighborhood for the best match (i.e., the best correlation). The size of the neighborhood is specified by the user. For correlation in an area of interest (AOI) with pre-specified intervals, 3 or more seed point/initial guess values may be required, and interpolation will be performed to calculate the values for every single subimage.

The inputted displacement values are primarily based on the user's experience or by observation of the deformation during tests. If the inputted displacement values are highly inaccurate, then the quality of the correlation output will be diminished.

The key difference between the seed point and initial guess settings lies in how the displacement values are inputted. For seed point settings, the displacement values are determined by applying the correlation algorithm. For initial guess settings, the user inputs the displacement values manually (with the assumption that the user knows the displacement that has occurred between the reference and correlation images).

NOTE: Seed point settings always take precedence over initial guess settings. If the user enables the seed point(s), any initial guesses that have been specified will be disregarded during correlation.

Calculating Correlation

After adding one or more reference images (and the related correlation images for each reference image), identifying one or more AOI regions within each reference image, and configuring the input parameters/settings for each reference image, the user may initiate the correlation calculation process at the click of a button.

Correlation may be calculated for all reference images and associated correlation images in the file. Alternatively, the user can narrow the scope and increase the calculation speed by performing correlation for only a single reference image or selected range of reference images (rather than all reference images in the file). Similarly, for a given reference image, the user may perform correlation for only a single correlation image or selected range of correlation images (rather than all the correlation images).

During correlation, the system will automatically analyze the AOI regions within the images and calculate measurements of surface deformation, displacement, gradient levels, and strain.

As the calculations are performed for each correlation image, the corresponding data chart for the correlation image is displayed. As the image is processed, the chart is dynamically populated with calculated data in real time.

Once the calculations for all selected images have been completed, the system will automatically exit calculation mode and return to edit mode. Alternatively, the user may manually stop the correlation process at any time and return to edit mode.

Correlation Data Charts

In RapidCorrelator, each correlation image has a corresponding data chart. When a correlation image is added, the system automatically creates a corresponding data chart frame displaying a prefabricated data chart.

When the correlation process is run, the data chart for each correlation image is automatically populated with the calculated results data for the correlation image.

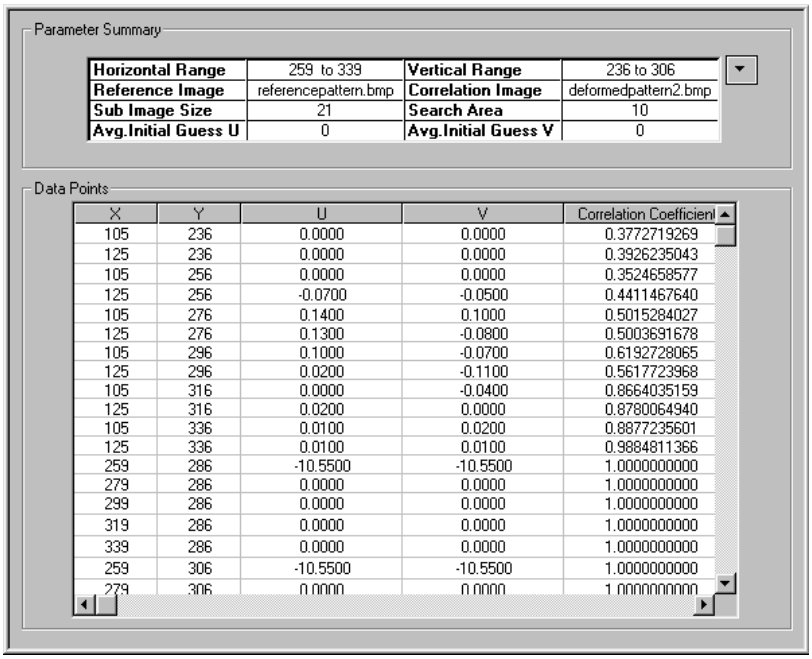

Figure 3: Correlation Data Chart

The data chart displays the parameter summary details for the correlation image, including the horizontal and vertical ranges, the file name of the related reference image, the file name of the correlation image, the size (in pixels) of the subimage and search area, and the average initial guess values for U and V displacements.

The data chart also lists all the calculated data points (X/Y axis, U/V displacements, and coefficients).

Exporting Correlation Data to Microsoft Excel Format

RapidCorrelator provides the capability of exporting calculated correlation data to a Microsoft Excel spreadsheet (XLS) file. The user may export the data for all correlation images in the file or only selected correlation images.

Applied Analysis

Once correlation has been run for a selected reference image and its related correlation images, the calculated data values for each correlation image can be generated graphically as applied analysis.

Applied analysis frames are visual contour maps used to illustrate and reveal displacements, strains, etc. The different types of applied analysis frames can be browsed and viewed by the user. Sets of applied analysis frames can also be played as linear or looping animation, which enables the user to view the dynamics of the strains, loads, displacements, etc.

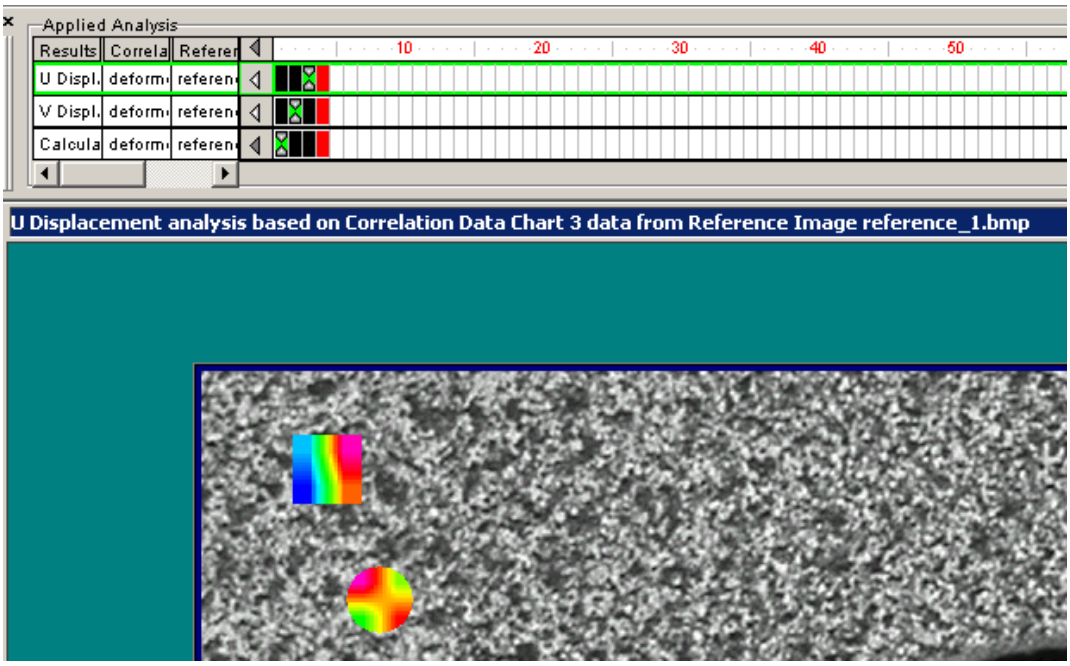

Figure 4: Applied Analysis Frame

The following types of applied analysis can be generated based on the results data calculated for any correlation image:

- **Displacement Analysis** – Displacement analysis based on the shift of the subimage (in pixels) from the reference image to the correlation image(s). There are 2 displacement options: "**U Displacements**" (to analyze the shift in the horizontal or x direction) or "**V Displacements**" (to analyze the shift in the vertical or y direction).
- **Calculated Gradient Analysis** – Gradient strain analysis based on the gradient velocity of the subimage from the reference image to the correlation image(s). There are 4 gradient options: **du/dx** (the first derivative of u with respect to x), **dv/dy** (the first derivative of v with respect to y), **du/dy** (the first derivative of u with respect to y), or **dv/dx** (the first derivative of v with respect to x).
- **Strains** – Various types of strain analysis. There are 3 main strain options: **Normal** (two different strain component formulae), **Shear** (one strain component formula), and **Principal** (two different strain component formulae).

NOTE: RapidCorrelator provides a **Scale Key** component, which is used to adjust the range of colors that identify result regions within applied analysis frames. Using the arrow buttons provided on the **Scale Key**, the user may adjust/stretch the range of color applied to the results contour map on each generated analysis frame.

Playback of Images

RapidCorrelator includes a built-in image player for animated playback of correlation images and applied analysis frames. This enables the user to see the progression of the deformations from one image to the next and view the dynamics of the strains, loads, displacements, etc.

At the click of a button, any selected set of images/frames can be played once or in a continuous loop.

By default, the images/frames are played in a linear path without any delays between frames. However, RapidCorrelator provides various options for controlling and customizing playback. Hyperlink buttons and validation keys may be added to frames in order to control the navigation between frames and facilitate non-linear navigation during playback. Transition time delays may also be specified for individual frames in order to determine how long each frame is displayed on screen during playback.

During playback, RapidCorrelator also displays a built-in **Playback Bar**, which includes controls for visually tracking the progress of playback and manually navigating between images/frames.

Rich-Media Annotation Features

RapidCorrelator's advanced annotation capabilities provide a layer of versatility not available in other software products of its kind. The rich-media suite of drag-and-drop objects, drawing tools, and other features enables the user to augment images and analysis with text, audio, video, graphics, shapes, interactive buttons, links, and more.

Annotations are extremely useful for enhancing the presentation of the images and explaining/highlighting different artifacts within the analytical results.

Edit and Draw Objects

In a RapidCorrelator file, each reference image, correlation image, and applied analysis frame may be populated with multiple objects.

RapidCorrelator provides two (2) types of annotation objects: **Edit Objects** and **Draw Objects**.

Edit Objects

Edit objects include text, graphics, and buttons. They are useful for labeling/describing various image elements as well as providing additional explanations and descriptions of graphical analysis items.

RapidCorrelator's Edit objects include the following:

- **Hyperlink** – Enables the user to add interactive buttons/links for use during playback of the selected set of images/frames. Hyperlinks can be used to navigate from frame to frame in a linear or non-linear manner. They can also be used to launch external files or web URLs, display pop-up text messages or images, and play audio/video clips.
- **Instruction Box** – Enables the user to add floating text windows to frames. Instruction boxes are useful for displaying notes and explanatory text.
- **Text Field** – Enables the user to add text directly to frames. Text fields can be styled as call-outs for purposes of labeling and identifying specific items or areas.

NOTE: Any text in a Text Field or Instruction Box can be made into an interactive link or "hotword". When clicked during playback, a hotword can display a user-defined message in a pop-up window or jump to another frame.

- **Image** – Enables the user to add pictures or graphics (BMP, GIF, JPEG, or PNG) to frames.

Draw Objects

Draw objects include various types of lines, colors and shapes. They are useful for pointing out, emphasizing, and/or highlighting relevant areas or portions of a frame.

RapidCorrelator's Draw objects include the following:

- **Fill Color** – Enables the user to change the color of a frame or shape object.
- **Line** – Enables the user to draw straight lines and arrows (for pointing to specific frame areas or elements, etc.).
- **Round Rectangle** – Enables the user to draw rounded rectangle shapes.
- **Rectangle** – Enables the user to draw regular rectangle shapes.
- **Ellipse** – Enables the user to draw elliptical shapes.
- **Color Selector** – Enables the user to select a color from any frame area or object and then apply the selected color to another frame or shape object.
- **Pencil** – Enables the user to draw free-form lines.
- **Air Brush** – Enables the user to draw free-form lines with an airbrush effect.
- **Paint Brush** – Enables the user to draw free-form lines with different levels of thickness and different styles.
- **Polyline** – Enables the user to draw straight lines with angles.
- **Polygon** – Enables the user to draw polygon shapes (i.e., any shape with 3 or more straight line segments).

Sound Support

RapidCorrelator enables the user to enhance images with a variety of sound:

Sound Linked to an Image/Frame

The user may link a sound file (ASF, .AU, .MP2, .MP3, or .WAV) to any correlation image or applied analysis frame. The sound file will play when the image/frame appears on screen during playback.

Sound Linked to a Hyperlink Button

The user may link a sound file (ASF, .AU, .MP2, .MP3, or .WAV) to a Hyperlink button added to a correlation image or applied analysis frame. The sound file will play when the button is clicked during playback.

Sound Recorder

RapidCorrelator's **Sound Recorder** allows the user to record sound from any available sound device. A sound clip can be recorded on any correlation image or applied analysis frame, and the recorded sound will run automatically during playback of the image/frame.

- After recording sound during the editing stage, the user can immediately play back the recorded clip to hear how it sounds.
- Sound can be recorded from any sound device present on the user's system, including CD-ROM and Microphone.
- A sound clip recorded on a frame may also be saved to disk as an audio file. The saved audio file may then be reused for other frames and objects.

Other Features

Frame Thumbnails

RapidCorrelator enables the user to access thumbnail images for any selected range of images/frames. A thumbnail image is a miniature representation of a frame with its image and all applied objects displayed.

By accessing the thumbnails view, the user may view multiple images/frames at a glance by quickly scrolling through the thumbnails.

Printed Documentation

Users may print RapidCorrelator files to paper to create document versions of content files.

The look and content of a printed document may be customized by configuring various available print settings, including selecting which images/frames to print, specifying the number of frames that will be printed on each page, specifying margin and header/footer settings, specifying whether to print the frame name/number along with each frame, specifying whether to print document details/properties text on a separate title page, and more.

In addition, before actually printing to paper, the user may access a Print Preview window to view virtual pages showing how each printed frame will look.

Resource Editor

The **Resource Editor** is RapidCorrelator's central repository of linked or embedded media files, including audio, video, images, icons, and cursors. It is used to retrieve and manage media files and associate them with specific objects and frames.

- The **Resource Editor** organizes files by extension into 7 main resource types:
  - **Images** – BMP, .GIF, .JPG, and .PNG image files.
  - **Video** – ASF, .AVI, .MOV, .MPEG, and .MPG video files.
  - **Audio** – ASF, .AU, .MP2, .MP3, and .WAV audio files.
  - **Icons** – ICO icon files.
  - **Cursors** – CUR cursor files.
  - **Default Icons** – A group of 56 default icons provided with RapidCorrelator.
  - **Default Cursors** – A group of 8 default cursors provided with RapidCorrelator.
- The **Resource Editor** manages all resources as components of resource (.RSE) files. It maintains a default RapidCorrelator resource (.RSE) file containing all imported file links. It also maintains a separate resource (.RSE) file for each opened RapidCorrelator file. (This .RSE file will be opened in the **Resource Editor** whenever the corresponding RapidCorrelator file is opened, and it will contain all imported file links assigned to objects and frames within the RapidCorrelator file).
- The user can replace or rename any selected resource link, and any selected resource link can be permanently removed from the **Resource Editor** (but not from the disk).
- A **Preview** window allows the user to see what a selected image, icon, or cursor file looks like before adding it to an object or frame.
- For each resource link, the user may specify one or more keywords to serve as tags for searching purposes. During a search of the **Resource Editor**, the user will enter a keyword, and all resource links with keywords that match the entered keyword will be displayed.

Global Objects

RapidCorrelator enables users to quickly reuse objects/elements across multiple frames by making them Global. Objects can be set to be Global across certain frames or all frames within the RapidCorrelator file.

This makes it easy to have similar objects/elements appearing across multiple frames. It also makes it easy to update the object/element (since modifying a global object/element automatically updates it on every frame where it is used). This also helps keep the file size down because only one copy of a global object/element is stored internally.

Object Grouping and Common Property Formatting

Multiple objects may be clustered into a group in order to be selected, edited, dragged, and resized as a single object. Groups may also be nested within other groups.

The common properties of multiple selected objects may be accessed in order to set properties for multiple objects simultaneously.

Spell Checker

RapidCorrelator includes a standard **Spell Checker**, which enables the user to scan images/frames and objects in order to detect and correct spelling errors.

During a spell check, if a word is not recognized, the user can click the **Add** button in the **Spell Checker** to add the word to the custom dictionary file. In addition, the user may edit the custom dictionary file directly (using any text editor) in order to add words to it.

Password Protection

RapidCorrelator enables users to assign passwords to files in order to prevent unauthorized editing. Once a password has been assigned to a file, the file can only be subsequently opened in RapidCorrelator once the correct password has been entered.

Contact Information

For more information on **RapidCorrelator v1.0**, please contact our sales team either by phone at (613) 731-9443 or by e-mail at **salessupport@xstreamsoftware.com**.

XStream Engineering
2280 St. Laurent Blvd., Suite 200
Ottawa, Ontario, CANADA
K1G 4K1

www.xstreameng.com

info@xstreameng.com (Information)
salessupport@xstreamsoftware.com (Sales)
techsupport@xstreamsoftware.com (Support)

Telephone: (613) 731-9443
Fax: (613) 731-9615