Introduction to Apama

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About this Guide

This *Introduction to Apama* is for new Apama users. It provides a high-level overview of Apama, describes the Apama architecture, discusses Apama concepts and introduces Software AG Designer, which is the main development tool for Apama.

Documentation roadmap

Apama provides documentation in the following formats:

- HTML (available from both the documentation website and the `doc` folder of the Apama installation)

- PDF (available from the documentation website)

- Eclipse help (accessible from Software AG Designer)

You can access the HTML documentation on your machine after Apama has been installed: Display the `index.html` file, which is in the `doc/apama-onlinehelp` directory of your Apama installation directory.

The following guides are available:

Title	Description
Release Notes	Describes new features and changes introduced with the current Apama release as well as earlier releases.
Installing Apama	Summarizes all important installation information.
Introduction to Apama	Provides a high-level overview of Apama, describes the Apama architecture, discusses Apama concepts and introduces Software AG Designer, which is the main development tool for Apama.
Using Apama with Software AG Designer	Explains how to develop Apama applications in Software AG Designer, which is an Eclipse-based integrated development environment.
Developing Apama Applications	Describes the the technology for developing Apama applications: EPL monitors. You can use this technology to implement a single Apama application. In addition, there are C++ and Java APIs for developing components that plug in to a correlator. You can use these components from EPL.
Connecting Apama Applications to External Components	Describes how to connect Apama applications to any event data source, database, messaging infrastructure, or application.
Building and Using Apama Dashboards	Deprecated. Describes how to build and use an Apama dashboard, which provides the ability to view and interact with DataViews. An Apama project typically uses one or more dashboards, which are created in the Dashboard Builder. The Dashboard Viewer provides the ability to use dashboards created in the Dashboard Builder. Dashboards can also be deployed as simple web pages. Deployed dashboards connect

Title	Description
	to one or more correlators by means of a dashboard data server or display server.
Deploying and Managing Apama Applications	Describes how to deploy Apama applications using Docker and Kubernetes. It also provides information for improving Apama application performance by using multiple correlators, for managing and monitoring Apama components over REST (Representational State Transfer), and for using correlator utilities and configuration files.

In addition to the above guides, Apama also provides the following API reference information:

- API Reference for EPL (ApamaDoc)

- API Reference for Java (Javadoc)

- API Reference for C++ (Doxygen)

- API Reference for .NET

- API Reference for Python

- API Reference for Component Management REST APIs

Online Information and Support

Product Documentation

You can find the product documentation on our documentation website at https://documentation.softwareag.com.

In addition, you can also access the cloud product documentation via https://www.softwareag.cloud. Navigate to the desired product and then, depending on your solution, go to "Developer Center", "User Center" or "Documentation".

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You can find helpful product training material on our Learning Portal at https://learn.softwareag.com.

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- Browse through our vast knowledge base.

- Ask questions and find answers in our discussion forums.

- Get the latest Software AG news and announcements.

- Explore our communities.

- Go to our public GitHub and Docker repositories at https://github.com/softwareag and https://containers.softwareag.com/products and discover additional Software AG resources.

Product Support

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- Download products, updates and fixes.

- Search the Knowledge Center for technical information and tips.

- Subscribe to early warnings and critical alerts.

- Open and update support incidents.

- Add product feature requests.

Data Protection

Software AG products provide functionality with respect to processing of personal data according to the EU General Data Protection Regulation (GDPR). Where applicable, appropriate steps are documented in the respective administration documentation.

1 Apama Overview

In addition to reading this *Introduction to Apama*, it is recommended that you do the following to become familiar with Apama. Work through the Apama tutorials in Software AG Designer. From the **Help** menu, choose **Welcome** to display the Welcome page, and then click **Tutorials** under the **Apama** heading. This displays links to interactive tutorials that provide step-by-step instructions for writing simple Apama applications that you can then run and monitor.

What is Apama?

Apama is an event processing platform. It monitors rapidly moving event streams, detects and analyzes important events and patterns of events, and immediately acts on events of interest according to your specifications.

Event-based applications differ from traditional applications in that rather than continuously executing a sequence of instructions, they listen for and respond to relevant events. Events describe changes to particular real-world or computer-based objects, for example, a new temperature reading from a factory sensor.

Events are collections of attribute-value pairs that describe a change in an object. For example, the figure below shows events from a sensor. Each sensor reading has a number of attributes, such as temperature and pressure.
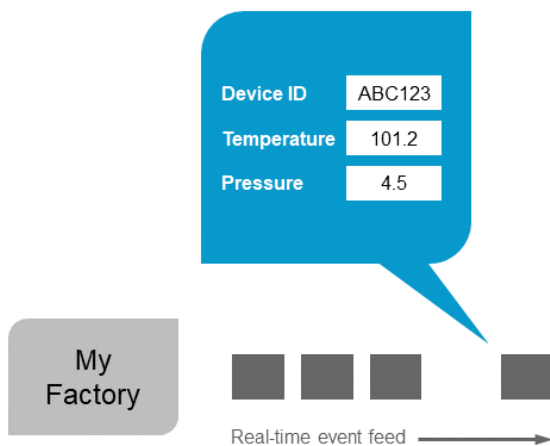
The attributes, or fields, of an individual event class may be of a variety of types, including numerical and textual data. Events with multiple fields can be viewed as multidimensional types, in that a search to find an event of interest might involve searching across several of the event fields.

Rather than executing a sequence of activities at some defined point, an event-based system waits and responds appropriately to an asynchronous signal as soon as it happens. In this way, the response is as immediate (or real-time) as possible.

The main Apama features include:

- Graphical development tools accessible to business users.

- EPL, which is a concise, richly-featured event processing language.

■ The connectivity plug-in API, which allows in-correlator integration with external data sources of varying formats.

■ Sophisticated analytics with native support for temporal arguments.

■ Sub-second response to detected events and patterns of interest.

■ Highly scalable, patented, event-driven architecture, supporting tens of thousands of concurrent scenarios.

■ Flexible event replay for testing new event scenarios and analyzing existing ones.

■ Tools for managing and monitoring your application.

The following functional diagram shows the main Apama features:
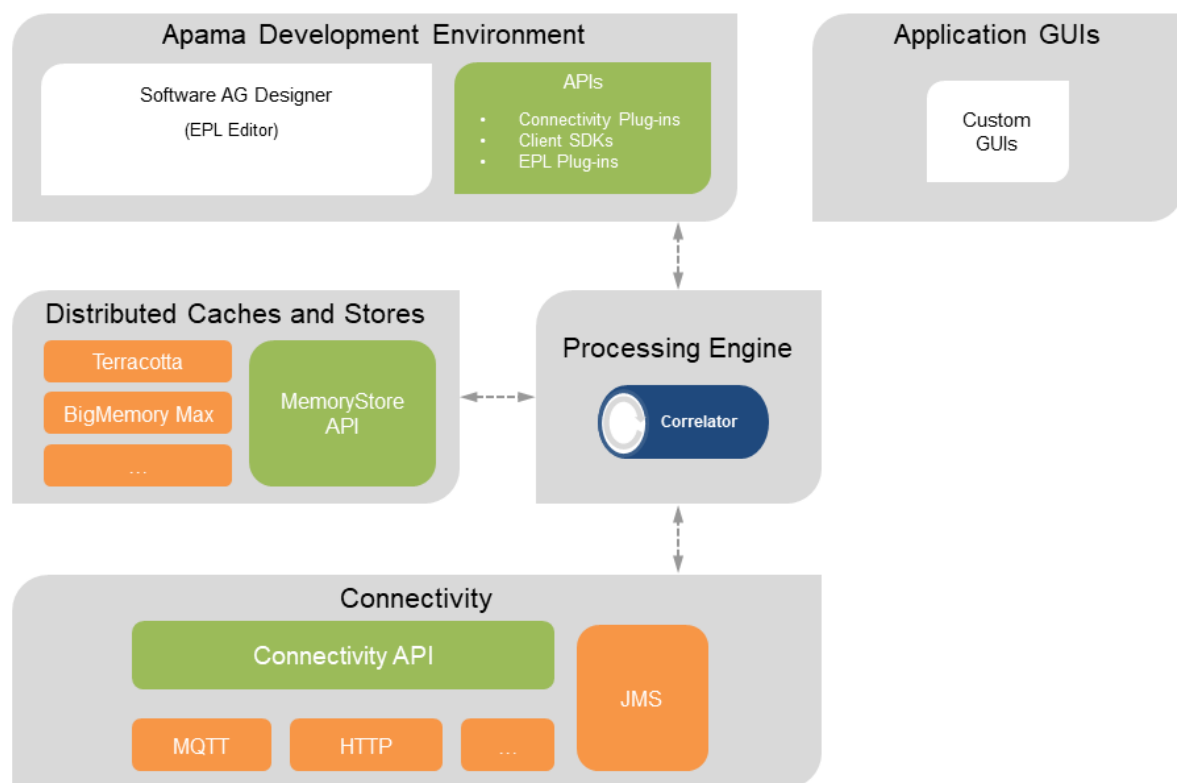
About Apama license files

A license file is required for the full functionality of Apama. Refer to the licensing terms specified in your software contract for any additional legal restrictions that may be imposed on your use of Apama. You can provide the Apama license file in the following ways:

■ Copy the license file to the Apama work directory (`APAMA_WORK/license`).

■ Specify the path to the license file by setting the `licenseFile` element in the YAML configuration file for the correlator. See "YAML configuration file for the correlator" in *Deploying and Managing Apama Applications*.

- Specify the path to the license file using the `-l` or `--license` command-line option when starting the `correlator` executable. See "Starting the correlator" in *Deploying and Managing Apama Applications*.

It is possible to run Apama without a license file or with an expired license file. Apama behavior with regard to the Apama license file is as follows:

- When a license file cannot be found, the correlator will run with reduced capabilities. See "Running Apama without a license file" on page 12.

- A correlator started with a license file does not shut down immediately when its license expires. It continues operation for seven days beyond expiration. After that, the correlator shuts down. The correlator logs periodic warning messages until it reaches the end of the seven days or until you replace the expired license.

- Removing the license file from a running correlator does not cause it to shut down immediately. It continues operation for seven days after the license file is removed. After that, the correlator shuts down. The correlator logs periodic warning messages until it reaches the end of the seven days or until you restore the license.

- You can start a correlator with an expired license if it is less than seven days beyond expiration.

If you want to continue with reduced capabilities after the correlator has shut down after seven days, you have to remove the license and then restart the correlator.

If you obtain a license file after you have been running Apama, copy it to the `license` directory in your `APAMA_WORK` directory, for example: `C:\Users\Public\SoftwareAG\ApamaWork_n.n\license\ApamaServerLicense.xml` (where *n.n* stands for the current version number).

If the correlator's license has expired, you have to obtain a new license file and copy it into the same location before the end of the above mentioned grace period. The correlator checks for an updated license file every five minutes, so the new license file is automatically picked up. The correlator does not need to be restarted in this case.

If you name the license file "ApamaServerLicense.xml" and put it in the `license` directory in `APAMA_WORK`, then the correlator will automatically pick up the license file. Otherwise, you must specify the path to the license file on the command line.

Note:

When you are using Apama in Cumulocity IoT, that is, the Streaming Analytics application, a valid license is automatically provisioned. See the Cumulocity IoT documentation at https://cumulocity.com/docs/streaming-analytics/overview-analytics/ for more information on the Streaming Analytics application.

Running Apama without a license file

Apama can be run without a license file in which case it runs with reduced capabilities and can be used for simple or exploratory use cases. Refer to "License Terms and Technical Restrictions" in the *Release Notes* for the current license terms and restrictions.

The following restrictions apply when starting the correlator without a license file:

- The correlator does not start more than 4 threads for EPL processing. The number of threads being used is logged. Up to 20 contexts may be created and all are runnable, but the correlator does not use more than 4 threads to execute EPL, limiting the correlator's performance.

- Reliable messaging with connectivity plug-ins is not permitted.

- Correlator-integrated messaging for JMS is limited to BEST_EFFORT only messaging (unreliable). It refuses to connect using reliable modes (EXACTLY_ONCE, AT_LEAST_ONCE or APP_CONTROLLED).

- The correlator logs that it is running without a license file.

The following restrictions are enforced while the correlator is running and a license file cannot be found:

- The correlator is limited to 1024MB of resident memory. If 1024MB of memory is exceeded, the correlator is stopped and an error is logged indicating that the correlator is running without a license file. There is a warning if the resident memory exceeds 90% of the 1024MB limit - though if the correlator's memory increases very quickly, the limit may be hit before the 90% warning is logged.

  Note that this limit also includes Java memory usage. It is recommended that you size your Java virtual machine to not consume too much memory. If you are using Java features, you may need to use -J-Xmx256M to limit the memory usage of your Java virtual machine to 256MB (or some suitable size less than 1024MB). Note that the memory usage may increase if a burst of events is received.

- The correlator does not allow more than 20 contexts to be created. The spawn statement throws an exception if it would create a new context and 20 contexts are already created. In addition, a startup error occurs when recovering a persistent database with more than 20 contexts. Both the exception and the startup error indicate that the correlator is running without a license file.

- The correlator does not allow more than 5 persistent EPL monitors (this does not include monitor instances of persistent monitors). An error is logged if there are more than 5 persistent monitors.

- The correlator does not allow the injection of user-generated correlator deployment packages (CDPs). If a user-generated CDP is injected, the correlator rejects the injection and an error is logged indicating that the correlator is running without a license file.

- The correlator does not allow more than 5 Apama query definitions to run and no more than 5 query instances per definition. When more than 5 query definitions are injected into the correlator, ERROR log messages are written.

  > **Note:**
  > Apama queries are deprecated and will be removed in a future release.

- The Apama query runtime drops events if there are already 50 different partition values for a query. When more than 50 partition values are sent in, ERROR log messages are written.

- If reliable JMS connections are requested dynamically, an exception is thrown which should be caught in EPL, and an error message is logged indicating that this configuration is not supported as the correlator is running without a license file.

The correlator info web page (`http://localhost:15903/info`) always shows you whether the correlator is currently running with or without a license file.

To find out if the above-mentioned limits have been exceeded, you can check the following:

- The correlator log file for most of the above-mentioned cases. See "Descriptions of correlator status log fields" in *Deploying and Managing Apama Applications*.

- The status messages of the `engine_watch` tool. See "Watching correlator runtime status" in *Deploying and Managing Apama Applications*.

- The `-a` (`--getall`) or `-Pm` (`--getpmemory`) option of the `engine_management` tool to get the physical memory usage. See "Shutting down and managing components" in *Deploying and Managing Apama Applications*.

- The scenario browser for status information on Apama queries. See "Using the Scenario Browser view" in *Using Apama with Software AG Designer*.

2 Apama Architecture

Apama architecture has a modular, scalable design with core features that

- Monitor inbound events typically delivered by a messaging infrastructure or market data feed.

- Analyze those events in memory, either singly or in conjunction with other events whose attributes and temporal ordering represent a pattern.

- Trigger outbound events that represent an action to be taken in response to the analysis.

As you can see, Apama's architecture is designed to process events. Event processing requires an architecture that is fundamentally different from traditional data processing architectures. Because Apama's architecture is event driven, an understanding of the distinctive qualities of this architecture is crucial to designing and building robust Apama applications.

Distinguishing architectural features

Apama inverts the paradigm of traditional data-centric systems. Rather than the "store > index > search" model of those architectures, Apama introduces the correlator — a real-time, event processing engine. An Apama application comprises monitors that specify the events or patterns of events that interest you. These specifications are the logical equivalent of database queries. After you load monitors into the correlator, incoming events flow over them and they monitor these event streams for the events and patterns you specified. When a matching event or pattern is found the correlator processes it according to the rules you specify.

Apama's architecture is further distinguished by its ability to support huge numbers of monitors operating simultaneously. Each can have its own logic for monitoring the event streams, seeking out patterns and, upon detection, triggering specified actions.

EPL, Apama's native event programming language, lets developers define rules for processing complex events. Such rules let the correlator find temporal and causal relationships among events.

Messages on a variety of transports carry events to and from correlators. Apama connectivity plug-ins translate application-specific data into Apama application event formats that the correlator can process.

Apama components can be connected to each other by executing the Apama `engine_connect` tool with specification of an explicit point-to-point connection.

The following figure illustrates the Apama architecture. Each component is described later in this section.
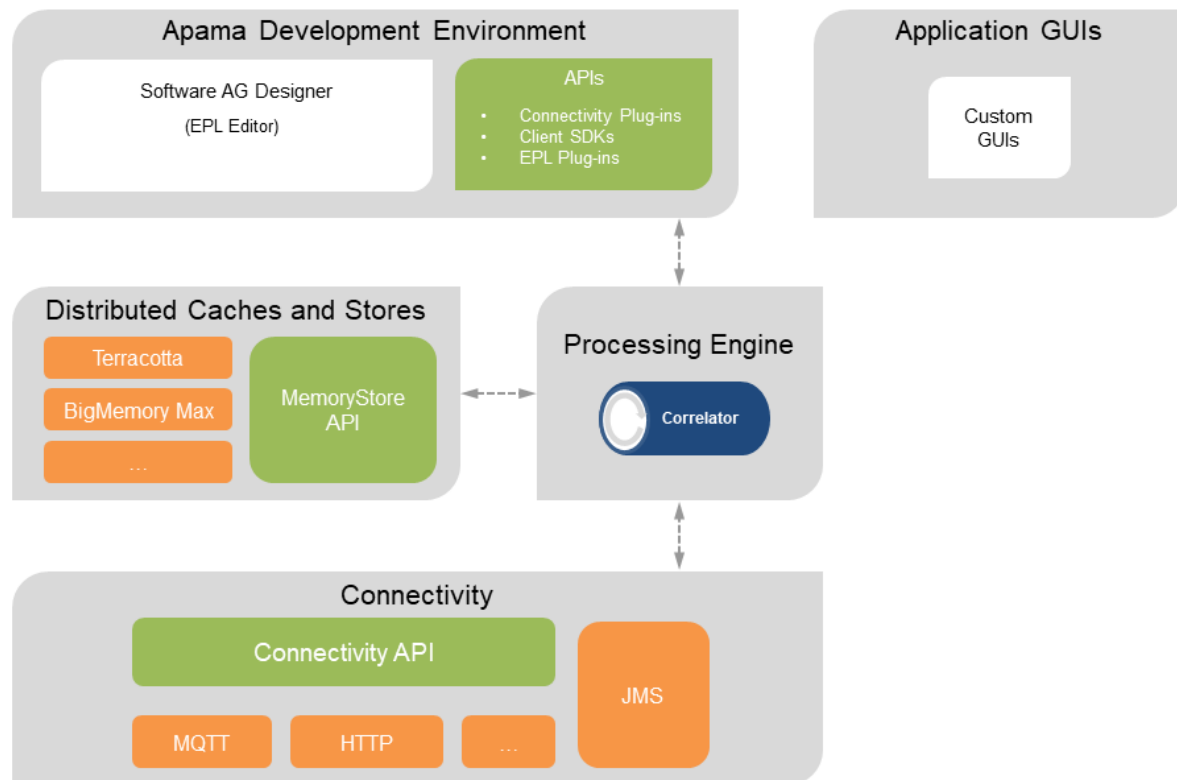
How Apama integrates with external data sources

You can connect Apama to any event data source, database, messaging infrastructure, or application. There are several ways to do this:

- Write transport and codec connectivity plug-ins.

- Develop custom client applications with Apama APIs for Java, .NET, and C++.

- Create applications that use correlator-integrated messaging for JMS.

- Use MQTT for communication between constrained devices, for example, devices with limited network bandwidth.

- Use Kafka for communication with the Kafka distributed streaming platform.

- Use Cumulocity IoT for communication with connected IoT devices.

Using connectivity plug-ins to connect with external data sources

Connectivity plug-ins can be written in Java or C++, and run inside the correlator process to allow messages to be sent and received to/from external systems. Individual plug-ins are combined together to form *chains* that define the path of a message, with the correlator host process at one end and an external system or library at the other, and with an optional sequence of message mapping transformations between them.

Connectivity plug-ins allow plug-ins to transform and handle delivery of events.

Connectivity plug-ins perform a similar role to the Apama client library, which allows Java or C++ code in an external process to send/receive messages to/from the correlator. If Apama events need to be made available within an external system, then consider connectivity plug-ins if the external system has a protocol (such as JSON over HTTP). If the external system hosts plug-ins via an API, then the client library may be a better fit.

For detailed information, see "Using Connectivity Plug-ins" in *Connecting Apama Applications to External Components*.

Using Apama APIs to connect with external data sources

A range of APIs let you extend Apama at the client and correlator levels for integration with other environments, such as Java, .NET or C++. In addition, you can extend correlator behavior with Java and C++ plug-ins that can call external function libraries from within an application.

For detailed information, see "Developing Custom Clients" in *Connecting Apama Applications to External Components*.

Using correlator-integrated messaging for JMS to connect with external data sources

Apama's correlator-integrated messaging for JMS provides an efficient way to receive and send JMS messages to and from Apama applications. It also provides for reliable messaging (guaranteed delivery) and duplicate detection.

For detailed information, see "Using the Java Message Service (JMS)" in *Connecting Apama Applications to External Components*.

Using MQTT for communication between constrained devices

Apama provides a connectivity plug-in, the MQTT transport, which can be used to communicate between the correlator and an MQTT broker, where the MQTT broker uses topics to filter the messages. MQTT messages can be transformed to and from Apama events by listening for and sending events to channels such as `prefix:topic` (where the prefix is configurable).

For detailed information, see "The MQTT Transport Connectivity Plug-in" in *Connecting Apama Applications to External Components*.

Using Kafka for communication with a Kafka distributed streaming platform

Apama provides a connectivity plug-in, the Kafka transport, which can be used to communicate with the Kafka distributed streaming platform. Kafka messages can be transformed to and from Apama events by listening for and sending events to channels such as `prefix:topic` (where the prefix is configurable).

For detailed information, see "The Kafka Transport Connectivity Plug-in" in *Connecting Apama Applications to External Components*.

Using Cumulocity IoT for communication with connected IoT devices

Apama provides several connectivity bundles which allow you to communicate with the IoT devices connected to Cumulocity IoT. For example, you can receive events from the devices, send operations to the devices, and query the state stored in the platform.

For detailed information, see "The Cumulocity IoT Transport Connectivity Plug-in" in *Connecting Apama Applications to External Components*.

Descriptions of Apama components

While traditional architectures can respond to events after they have happened, Apama's event-driven architecture responds in real time to fast moving events of any kind. Apama applications leverage a platform that combines analytic sophistication, flexibility, performance and interoperability. In addition to being an event processing engine, Apama provides sophisticated development tools, a flexible testing environment, and an extensible connectivity framework. This makes Apama a comprehensive event processing platform for building real-time, event-driven applications.

Description of the Apama correlator

Apama's correlator is the engine that powers an Apama application. Correlators execute the sophisticated event pattern-matching logic that you define in your Apama application. Apama applications track inbound event streams and listen for events whose patterns match defined conditions. The correlator's patented architecture can monitor huge volumes of events per second

When an event or an event sequence matches an active event expression, the correlator executes the appropriate actions, as defined by the application logic.

- The correlator can concurrently search for and identify vast numbers of discrete event patterns with sub-millisecond responsiveness.

- The correlator can deliver low latency analytics on multiple inbound data streams by monitoring the event streams for patterns you specify.

- The correlator goes beyond simple event processing to deliver actionable responses.

See also "How the correlator works" on page 23.

Description of Apama EPL

EPL is Apama's native event processing language. You can find complete information in *Developing Apama Applications*.

Before EPL can look for patterns in event streams, you must define the types of events you are interested in and inject their definitions in the correlator. An event definition informs the correlator about the composition of an event type. An example event definition for a stock exchange tick feed is as follows:

```
event StockTick {
```

```
    string symbol;
    float price;
    float volume;
}
```

Each field of the event has a type and a name. The type informs the correlator how to handle that field and what operations to allow on it. As you can see, the correlator can handle multiple types, such as numeric values and textual values, within the same event type. Apama can handle any number of different event types at one time.

External event sources such as connectivity plug-ins and clients need to be able to send events into the correlator. For the correlator to be able to detect an event of interest, the event's type definition must have been loaded into the correlator. An example of a `StockTick` event is as follows:

```
StockTick ("APAMA", 55.20, 250010)
```

Apama monitors

A monitor defines:

- **One or more listeners.** EPL provides event listeners and stream listeners.

  - An event listener observes the correlator event stream analyzing each event in turn until it finds a sequence of events that match its event expression. When this happens the event listener triggers, causing the correlator to execute the listener action.

  - A stream listener passes stream query output to procedural code. A stream query operates on one or two streams to transform their contents into a single output stream. The type of the stream query output items need not be the same as the type of the stream query input items. The output for one stream query can be the input for another stream query. At the end of the chain of stream queries, a stream listener coassigns each stream query output item to a variable and executes specified code.

- **One or more actions.** An action is one or more operations that the correlator performs. An action might be to register a listener or it might be an operation to perform when the correlator finds a match between an incoming event or sequence and a listener.

The following EPL example illustrates these concepts in the form of a simple monitor called `PriceRise`. The monitor is composed of three actions. The first two actions declare listeners, which are indicated by the `on` keyword.

```
monitor PriceRise
{
    action onload() {
        on all StockTick("IBM",>=75.5,*) as firstTick {
            furtherRise (firstTick);
        }
        from tick in all StockTick(symbol="IBM")
            within 60.0 every 60.0
            select mean(tick.price) as f { average(tick.price); }
    }
    action average(float av) {
        log "60-second average for IBM: "+av.toString();
    }
    action furtherRise(StockTick tick) {
```

```
      on all StockTick("IBM",>=(tick.price*1.05),*) as finalTick {
          log "IBM has hit "+finalTick.price.toString();
          send Placeholder("IBM",finalTick.price,1000.0) to "PlaceholderChannel";
      }
   }
}
```

When a monitor starts running, the correlator executes the monitor's `onload()` action. In the `PriceRise` monitor, the `onload()` action creates an event listener for all IBM stock ticks that have a price above `75.5` at any volume and a stream listener for all IBM stock ticks. Since the last field of the event (`volume`) is irrelevant to the event listener it is represented by an asterisk (*), which indicates a wildcard. This monitor effectively goes to sleep until the correlator detects an IBM stock tick.

If the correlator detects an IBM stock tick, the stream listener takes it as input and uses it to log 60-second averages for IBM stock prices. If the IBM stock tick also has a price that is greater than or equal to 75.5, the correlator copies the field values in that event to the `firstTick` variable and calls the `furtherRise()` action.

The `furtherRise()` action creates another event listener. This event listener is looking for the next part of the event pattern, which involves detecting if the IBM stock price goes up by more than 5% from its new value. The second listener uses the `firstTick` variable to obtain the `price` value in the event that caused the first listener to detect a match. If the price rise occurs, the correlator copies the values in the matching, incoming event to the `finalTick` variable, and executes the associated block of code.

The associated block of code logs the new price and sends a `PlaceSellOrder` event to a receiver that is external to the correlator. For example, an adapter can pick up this event, and translate it into a message that an order book can operate on. The `PlaceSellOrder` event causes placement of an order for 1000 units of IBM stock.

Description of Software AG Designer

Software AG Designer is the main entry point for Apama development. When you are ready to start developing your Apama application, open Software AG Designer and create an Apama project to contain your application files.

Complete information is in *Using Apama with Software AG Designer*.

Description of Dashboard Builder and Dashboard Viewer

Note:
Apama dashboards are deprecated and will be removed in a future release.

Apama's Dashboard Builder enables you to create end-user dashboards and prepare them for deployment. For applications written in EPL, you create DataViews and use Dashboard Builder to create a dashboard from the DataViews.

Dashboard Builder is a visual design environment. A primary goal of Dashboard Builder is to enable non-technical users to create sophisticated dashboards. Consequently, Dashboard Builder provides a complete design and deployment environment. With a wide range of visual objects

and drag-and-drop development, Dashboard Builder provides the tools needed to create highly customized dashboards from which users can start/stop, parameterize and monitor Apama DataViews.

Dashboard Builder offers an extensive array of graphical widgets with which to build custom user dashboards. Meters, gauges, tables, graphs, and scales are available for creating highly customized dashboards. You can further personalize the interface through addition/deletion of panels or modification of graphics and color schemes.

Dashboard Viewer is the tool that end-users run to access dashboards.

See also "Building Dashboard Clients" and "Using the Dashboard Viewer" in *Building and Using Apama Dashboards*.

Description of client development kits

Apama is highly extensible with a range of APIs provided at the client and correlator levels. You can use these APIs to integrate with other environments, such as Java, JavaBeans, C++, or .NET. You can extend correlator behavior with plug-ins that can call external function libraries from within an application scenario.

See "Developing Custom Clients" in *Developing Apama Applications*.

Description of Apama's Data Player

Note:
Apama's Data Player and the Apama Database Connector (ADBC) are deprecated and will be removed in a future release.

Data Player, which runs in Software AG Designer, accelerates the development/deployment cycle of EPL applications by letting you pre-test (via simulation) your applications on event streams captured in Apama. It also supports flexible event processing replay features.

Data Player provides analysis tools for the Apama environment. It enables Apama users to investigate the likely behavior of Apama applications prior to deployment, as well as analyze the actual performance of those applications already in production.

Data Player operates on data captured by the Apama Database Connector (ADBC). ADBC provides Apama standard adapters that allows access to JDBC/ODBC compliant databases as well as to Apama Sim files. Analysis can include all events received by Apama or only selected event streams. Likewise, you can choose specific segments of time from the past (for example, an entire day, a specific 30 minute period, or any user chosen time slice). Additionally, you can accelerate replay speeds many times the actual live speeds, or slow them down or pause for more careful exploration of event processing operations.

See *Using Apama with Software AG Designer* for information about the Data Player. See *Connecting Apama Applications to External Components* for information about the ADBC adapter.

How the correlator works

The following figure shows the inner details of a running correlator. After the figure, there is a detailed discussion of how the correlator works.
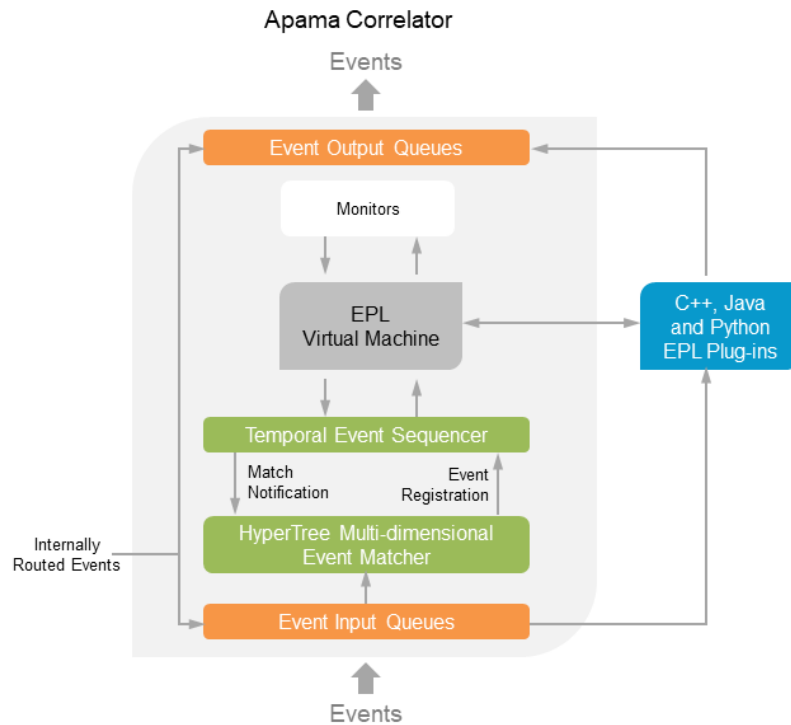
Monitors identify event patterns of interest and the responses to take if those patterns are detected. You use EPL to write monitors directly. Apama uses the Software AG Designer development environment for writing source code for monitors.

The correlator does not just execute loaded monitors in a sequential manner, as if they were traditional imperative programs. Instead, the correlator loads its internal components (the hypertree and the temporal sequencer) with the monitoring specifications of the monitors. The in-built virtual machines execute only the sequential analytic or action parts of the monitors.

The correlator contains the following components:

■ **HyperTree multi-dimensional event matcher**

The event matcher contains data structures and algorithms designed for high performance, multi-dimensional, event filtering. The correlator loads the event matcher with event templates. An event template identifies the event you are interested in. Logically, an event template is a multi-dimensional search. For example, a template for an IoT sensor might have values such as the following:

■ `deviceId: *`

■ `deviceType: TemperatureSensor`

- `uptime: > 5`

- `temperature: 20.0 <- -> 22.5`

This event template expresses a multi-dimensional search over sensor measurement events. The template will match events from devices of type `TemperatureSensor` which have been online for at least 5 seconds and have a temperature between 20.0 and 22.5 degrees. The individual `deviceId` is irrelevant to this search and so a `*` wildcard is used.

This kind of multi-dimensional, multi-type, ranged searching is what the event matcher was specifically designed for. In checking whether an incoming event matches any of the registered event templates, the event matcher exhibits logarithmic performance. This means that vast numbers of event templates can be queried against, with the minimum possible performance tail-off.

An event template is the basic unit of monitoring. A simple monitor might have one or a few event templates. A more complex monitor might have many. A monitor needs to load event templates only when events that match the specification are relevant to the monitor: in a multi-stage monitor, a monitor can insert and remove several event templates as the monitoring requirements change.

- **Temporal and stream sequencer**

The temporal and stream sequencer builds upon the single event matching capabilities of the event matcher to provide multiple temporal event and stream correlations. With EPL, you can declare a temporal sequence such as "tell me when any news article event is followed within 5 minutes by a 5% fall in the price of the stock the news article was about". This is a temporal sequence, with a temporal constraint. The sequence is a news article event, followed by the next stock price event, and then another stock price event with a price 5% less than the previous price event. The temporal constraint is that the last event occurs within 5 minutes of the first event.

The sequencer manages this temporal monitoring process, using the event matcher to monitor for appropriate event templates. This capability saves the programmer from having to encode such complex temporal logic through less intuitive imperative logic.

- **Monitors**

The correlator provides the capability for monitors to be injected as EPL. The number of monitors that can be loaded into a single correlator are only limited by memory size. When loaded, a monitor configures the hypertree and temporal sequencer with event templates for monitoring. The correlator stores the monitor internally and executes actions in the appropriate virtual machine in response to event detection.

Each monitor instance has its own address space within the correlator for storage of variables and other state. Monitor temporary storage size is limited only by the memory size of the host machine.

- **Event input queue**

External interfaces, such as connectivity plug-in chains, send events into the correlator. To start the monitoring process, the correlator injects each event, in the order in which it arrives, into the hypertree. Any matches filter through the temporal sequencer and invoke required

actions in the virtual machines. Some actions might cause events to be queued for output. During peak event input flow, events might wait on an input queue for an extremely brief moment.

- **EPL virtual machine**

  In response to detected event patterns of interest, the EPL virtual machine executes EPL. The fact that the correlator behaves this way, rather than continuously executing imperative code, is another reason for its high performance. Also, you can implement parallel processing in your applications so that the correlator can concurrently execute code in multiple monitors.

- **Event output queue**

  Monitor actions can output events to be communicated to other monitors or to external systems. When a monitor routes an event, the event goes to the front of the input queue. This ensures that any monitors that are listening for that event immediately detect it. When a monitor generates an event for an external receiver the event goes to an output queue for transmission to the appropriate registered party.

  When you use the correlator in conjunction with connectivity plug-ins, then an output event might represent an action on an external service. The connectivity plug-in transforms the output event into an invocation of the external service. An example is an event that places an order into the order book of a Stock Exchange.

- **EPL plug-ins**

  It is possible to extend the capabilities of the correlator through an EPL plug-in. An EPL plug-in is an externally-linked software module that registers with the correlator through the correlator's extension API. EPL plug-ins are useful when programming libraries of useful real-time functions have been built up. These functions can be made available as objects that can be invoked by EPL actions.

  Apama provides a number of standard EPL plug-ins:

  - The MemoryStore plug-in lets monitors share in-memory data.

  - The TimeFormat plug-in helps you format dates and times.

- **State persistence**

  When the correlator shuts down the default behavior is that all state is lost. When you restart the correlator no state from the previous time the correlator was running is available. You can change this default behavior by using correlator persistence. Correlator persistence means that the correlator automatically periodically takes a snapshot of its current state and saves it on disk. When you shut down and restart that correlator, the correlator restores the most recent saved state.

  To enable persistence, you indicate in your EPL code which monitors you want to be persistent. Optionally, you can write actions that the correlator executes as part of the recovery process. When code is injected for a persistence application, the correlator that the code is injected into must have been started with a persistence option. Persistent monitors are written in EPL. State in chunks, with a few exceptions, cannot be persistent.

You program the correlator by injecting monitors that you write in EPL.

When events are sent to the correlator, the correlator processes events by comparing the events to what listeners are active in the correlator. Each external event matches zero or more listeners. The correlator executes a matching event's associated listeners in a rigid order. The correlator completes the processing related to a particular event before it examines the next event. If the processing of an event generates another event that is routed to the correlator, the correlator processes all routed events before moving on to the next event in its queue. If a listener action block does not route events, the next external event is considered.

3 Apama Concepts

This section discusses the concepts that are central to all Apama applications. A thorough understanding of these concepts can help you design and develop more robust Apama applications.

Event-driven programming

Events are data elements. Each event is a collection of attribute-value pairs that capture the state (or changes to state) of real-world or computer-based objects. Events consist of data and temporal attributes that represent the *what*, *when*, and *where* of an object. This can be the state of an object or the interaction of objects at a particular time. Real world examples of events include:

- Sensor measurements from devices in a smart factory

- Stock market trades and quotes

- RFID signals

- Satellite telemetry data

- Card swipes at a turnstile

- ATM transactions

- Network activities/faults

- Troop movement on a battlefield

- Activity on a website

- Electronic funds transfers

- SCADA alerts (Supervisory Control and Data Acquisition)

Processing events requires event-driven programming. The hallmarks of event-driven programming include the following:

- Program execution does not flow sequentially from beginning to end. There is no standard starting point.

- Program execution happens in response to the arrival of events. Some external source pushes the events into your program.

- Events arrive in asynchronous messages.

- There are two main bodies of code: code that analyzes incoming events to determine if the events are of interest and code that performs actions when events of interest are found.

There are a lot of similarities between GUI programming and event driven programming. For example, in a GUI program you typically write code that responds to mouse clicks.

See also *Developing Apama Applications*, "How EPL applications compare to applications in other languages".

Complex event processing

Complex Event Processing (CEP) is software technology that enables the detection and processing of

- Events derived from other events. A derived event is an event that your application generates as a result of applying a method or action to one or more other events.

- Event sequences, often with temporal constraints.

CEP programs find patterns in event data that enable detection of opportunities and threats. Timely responses are then pushed to the appropriate recipients. The responses can be in the form of automated events, such as placing orders in algorithmic trading systems, or alerts to someone using Business Activity Monitoring (BAM) dashboards. The result is faster and better operational decisions

EPL provides the features needed to write applications that can perform CEP. The following example shows how EPL can concisely define event patterns and rules.

The NewsCorrelation monitor's onload() action defines a listener that specifies a complex event expression. The literal translation of the expression is "look for all news articles about any stock, followed by a 5% rise in the value of that stock within 5 minutes". This is the kind of implied news impact that might be of interest to a trader or a market risk analyst.

```
monitor NewsCorrelation {
   action onload() {
      on all NewsItem() as news {
         on StockTick(symbol=news.subject) as tick {
            on StockTick(symbol=news.subject,
                          price >= (tick.price*1.05))
               within(300.0) alertUser;
         }
      }
   }
   action alertUser() {
      log "News to price movement Correlation for stock "
                +news.subject+" has occurred";
   }
}
```

The on keyword specifies a listener. The initial listener nests two additional listeners that define the event sequence of interest. The listeners do the following:

1. The initial listener watches for all NewsItem events.

2. Each time the correlator detects a NewsItem event, this listener captures it in a news variable.

3. The first nested listener then watches for a StockTick event for the stock that the news item was about. This listener uses the news variable to access the information from the previously detected event.

4. When the correlator detects a matching StockTick event, the first nested listener captures it in the tick variable.

5. The innermost listener then watches for another `StockTick` event for the same stock but with a price that is at least 5% higher than the price in the event captured by the `tick` variable. The `within` keyword indicates that the correlator must detect the second `StockTick` event within 300 seconds (5 minutes) of finding the initial `NewsItem` event.

6. If the correlator finds a second `StockTick` event that matches within 5 minutes, the monitor sends a message to the log file. The nested listeners terminate.

   If the correlator does not find a second `StockTick` event that matches within the 5 minutes, the nested listeners terminate without sending a message to the log.

Understanding monitors and listeners

An introduction to monitors and listeners is in "Description of Apama EPL" on page 19. As mentioned there, monitors are the basic program component that you inject into the correlator. You write monitors in EPL.

A monitor defines:

- One or more listeners. A listener is the EPL mechanism that specifies the event or sequence of events that you are interested in. Conceptually, listeners sift through the streams of events that come in to the correlator and detect matching events.

- One or more actions. An action is one or more operations that the correlator performs. An action might be the registration of a listener or it might be the execution of an operation when the correlator finds a match between an incoming event or sequence and a listener.

When the correlator executes an `on` statement, it creates a listener. A listener watches for an event, or a sequence of events, that matches the event expression specified in the `on` statement. An event expression defines one or more event templates. Each event template defines an event type to look for, and specifies whether the event's fields should have any specific values. In addition, listeners can specify

- Temporal constraints. For example, a listener can specify that two events of interest must be received within 10 minutes.

- Logic. For example, a listener can specify that it is interested in event `A` or event `B` or event `C`.

It is often desirable to listen, separately but concurrently, for different instances of the same event type. For example, you might want to listen for and process, separately but concurrently, stock tick events for different stocks. EPL accomplishes this by letting a monitor instance spawn other monitor instances.

In the monitor code, you spawn a monitor instance by specifying the `spawn` keyword followed by an action. Each act of spawning creates a new instance of the monitor.

When the correlator spawns a monitor instance, it does the following:

1. The correlator creates a new monitor instance from the original monitor instance. The new monitor instance is almost identical to the original. The new monitor instance has a copy of the variables from the original but the active listeners from the original monitor instance are not copied.

2. The correlator invokes the named action on the new monitor instance.

Monitors that contain spawn statements typically act as factories, creating new monitor instances that all listen for the same event type but where each listens for events that have different values in one or more fields. Also, monitors can spawn to particular threads, referred to as *contexts* in EPL. This enables the correlator to concurrently process multiple monitor instances. (You must create contexts in EPL to implement parallel processing. You can refer to contexts from EPL.)

The lifecycle of a monitor is as follows:

1. You use Software AG Designer or a correlator utility to inject the EPL that defines the monitor into the correlator.

2. The correlator creates the original monitor instance, including space for variables as needed.

3. The correlator executes the monitor instance's onload() action.

4. The original monitor instance might spawn several times creating new monitor instances. For each spawned monitor instance, the correlator creates a copy of the original monitor instance's variable space and then executes the specified action.

5. A monitor instance terminates when it has no active listeners. Upon termination, the correlator invokes the monitor instance's ondie() method, if one is defined. Note that it is possible for a monitor instance to remain active after the monitor instance that spawned it has terminated.

6. When the last instance of a particular monitor terminates, the correlator calls the monitor's onunload() method, if it defines one. The last monitor instance to terminate might be the original monitor instance or a spawned monitor instance. Regardless, when the last instance terminates the correlator invokes the monitor's ondie() method and then the monitor's onunload() method, if these methods are defined.

   For example, suppose that a monitor definition specifies an ondie() method and an onunload() method. You inject this monitor and the correlator creates the original monitor instance. The original monitor instance spawns 9 times. Consequently, there are 10 instances of that monitor in the correlator. After all of these monitor instances have terminated, the correlator will have called ondie() 10 times and it will have called onunload() once.

See "Getting Started with Apama EPL" in *Developing Apama Applications*.

4 Getting Ready to Develop Apama Applications

The discussions in the following topics provide a foundation for developing your Apama application.

Becoming familiar with Apama

To become familiar with Apama, you should

■ Work through the tutorials in Software AG Designer. On the Welcome page, click **Tutorials** under the **Apama** heading. The tutorials provide step-by-step instructions for developing EPL applications.

■ Examine sample code. Your Apama installation directory contains a `samples` directory that contains many examples of monitors, EPL plug-ins, Apama client programs, and more.

■ Read all of this material, *Introduction to Apama*, so that you have a broad understanding of what Apama is all about.

■ Understand what is covered in the Apama user documentation. Peruse the documentation so that you know where to look for particular information. You can then refer to the documentation for the component you need to use.

Introduction to Software AG Designer

Software AG Designer is the main tool for implementing Apama applications. It contains a set of Eclipse plug-ins that provides a number of Eclipse perspectives:

■ Use the Apama Workbench perspective when you are new to Apama. This perspective provides a simplified view of Apama features that makes it easy to get started developing Apama applications.

■ Use the Apama Developer perspective when you are comfortable using the Apama Workbench perspective. The Developer perspective gives you far more control over your Apama project than the Apama Workbench perspective. For example, you can view more than one Apama project at one time, and you can specify launch configuration parameters.

■ Use the Apama Runtime perspective for monitoring and debugging the execution of Apama applications.

■ Use the Apama Debug perspective to debug your Apama application. The Debug perspective allows you to set break points, examine variable values, and control execution.

■ Use the Apama Profiler perspective to profile your Apama application. The Profiler perspective allows you to see which components of your application are consuming the most CPU time or to see if there are other bottlenecks in the application.

When developing an Apama application, the first step is to create an Apama project to contain your application files. An Apama project is a convenient way to manage the various files that make up your application. For example, an Apama application can include the following types of files:

■ EPL files (`.mon` extension).

- Files that contain sample events (.evt extensions).

- C++, Java and .NET files that contain Apama client applications or EPL plug-ins.

- Text, HTML or XML files.

You can add and manage all of these files from your Apama project in Software AG Designer. In addition, Software AG Designer provides an EPL editor whose features include content assistance, auto-bracketing, templates for frequently entered constructs, and problem detection. After you build an Apama project, Software AG Designer flags any line that contains an error.

You can use Software AG Designer to test your application. Software AG Designer provides Apama features that inject your application into the correlator, send test event streams to the correlator, launch adapters, and configure and monitor the operation of your application in a test environment.

Finally, Software AG Designer provides tools for packaging your application so that you can deploy it. See "Overview of Developing Apama Applications" in *Using Apama with Software AG Designer*.

Steps for developing Apama applications

Typically, Apama development is an iterative cycle:
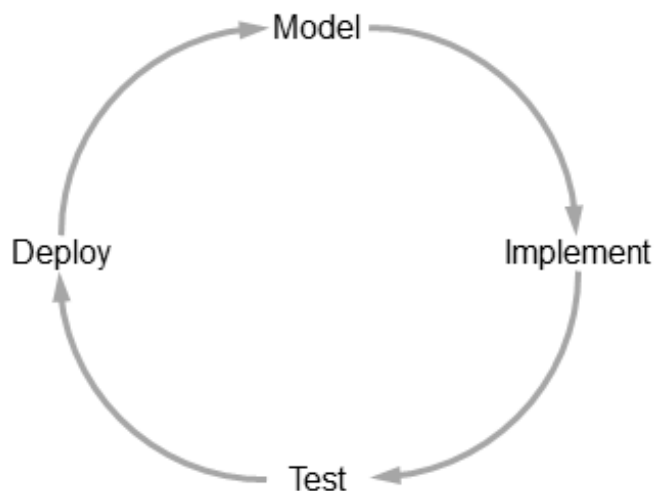
Multiple contributors with varying expertise can work concurrently to develop an Apama application.

The main steps for developing an Apama application include:

1. **Model**: Design your application. Important tasks are modeling the events that your application needs to handle and identifying the services that your application must provide.

2. **Implement**: Use Software AG Designer to create an Apama project to contain your application files (EPL files, event files, and so on). Since Apama applications typically consist of many components, it is often possible to concurrently implement them, particularly if several people are working on the application:

    - Write EPL programs in Software AG Designer.

- Develop Apama client applications.

- Implement or develop connectivity plug-ins.

- Develop EPL plug-ins that extend the correlator's standard features.

3. **Test**: In Software AG Designer, Apama provides a runtime perspective and Scenario Browser view that help test applications as they are built. You can automate testing through the use of command-line clients.

4. **Deploy**: Docker containers (on Linux) are a great way to deploy Apama applications. Or use the macro definitions in the Ant script that is provided with Apama. You can also use the Ant export wizard in Software AG Designer to generate a simple Ant script for deploying your Apama project. Tune Apama applications for optimum performance.

   See "Overview of Deploying Apama Applications" in *Deploying and Managing Apama Applications*.

Overview of starting, testing and debugging applications

Software AG Designer provides tools for running your Apama application in a test environment.

In the Apama Workbench perspective, click the Start button to start a correlator and inject the current project. The **Scenario Browser** panel is then shown. Use the Scenario Browser to examine parameter values during execution. You can monitor execution in the **Console** and **Problems** panes.

In the Apama Developer perspective, select the project you want to test. Select **Run** from the menu bar and then select whether you want to run, debug or profile your Apama application. You can specify one or more launch configurations for your project.

In the Apama Runtime perspective, you can monitor your running application.

In *Using Apama with Software AG Designer*, see "Launching Projects" and "Debugging EPL Applications".

5 Apama Glossary

action

An action is a block of code. Optionally, an action can have parameters and/or a return type. An action can be called, typically as part of responding to an event listener. Actions can be members of monitors or events. The following action names have special meanings and may be called by the correlator:

- On monitors only: `onload()`, `ondie()`, `onunload()`

- On monitors and events: `onBeginRecovery()`, `onConcludeRecovery()`

activation

When the passage of time or the arrival of an item causes a stream network or an element in a stream network to process items.

aggregate function

A function that operates on all items in a stream query window, for example, `sum()`.

batch

When you define a window in a stream query, you can specify that you want to update the window in batches. A batch can be a certain number of items, or it can be the items that arrived in a certain length of time.

bundle

When using Apama in Software AG Designer, a bundle is a named collection of Apama-provided objects that are required to execute a particular type of Apama application. Typically, a bundle includes EPL files, event definition files and event files, but it can include a wide range of file types such as configuration files.

.cdp

File extension for Apama correlator deployment packages.

CEP

Complex event processing. CEP technologies let you detect and process events derived from other events, and sequences of events with or without temporal constraints.

channel

Adapter and client configurations can specify the channel to deliver events to. A channel is a string name that contexts and receivers can subscribe to in order to receive particular events. In EPL,

you can send an event to a specified channel. Sending an event to a channel delivers it to any contexts that are subscribed to that channel, and to any clients or adapters that are listening on that channel.

connectivity plug-in

A C++ or Java class running inside the correlator that can transform and transmit messages between the correlator and external data sources.

context

Contexts allows EPL applications to organize work into threads that the correlator can concurrently execute. In EPL, `context` is a reference type. When you create a variable of type `context`, or an event field of type `context`, you are actually creating an object that refers to a context. The context might or might not already exist. You can then use the context reference to spawn to the context or enqueue an event to the context. When you spawn to a context, the correlator creates the context if it does not already exist.

correlator

Event correlation engine. The part of Apama that looks for events of interest, analyses matching events, and executes appropriate actions.

correlator deployment package

A correlator deployment package (CDP) is a file that contains application EPL code in a proprietary, non-plain-text format. These files treat EPL files similarly to the way Java files are treated in JAR files. CDP files can be created by exporting from Apama projects in Software AG Designer or by using the `engine_package` utility. CDP files can be injected to the correlator.

correlator-integrated messaging for JMS

Apama's correlator-integrated messaging for JMS provides an efficient way for Apama applications to send messages and to receive JMS messages for processing. Correlator-integrated messaging for JMS also provides for reliable messaging (guaranteed delivery) and duplicate detection.

.csv

File extension ("comma separated values") for some exported data; suitable for third party applications such as spread sheets.

current events

The set of current events contains the events in the window(s) of a partition.

DataView

Table structure that contains event fields that you specify.

EPL

The Apama Event Processing Language (EPL) is an event-based scripting language that is an interface to the correlator.

EPL plug-in

EPL plug-ins are C++ code modules or Java classes that you write to extend the capability of an Apama component. Apama provides APIs that let you write EPL plug-ins for correlators and adapters.

event

An occurrence of a particular circumstance of interest at a specific time that usually corresponds to a message of some form. The message is a collection of attribute-value pairs that describe a change in an object.

event collection

The process of storing events that stream through the correlator. The collected events can be exported to spreadsheet applications.

event listener

An event listener observes the correlator event stream, analyzing each event in turn until it finds a sequence of events that match its event expression. When this happens, the event listener triggers, causing the correlator to execute the listener action. See also "stream listener" on page 44.

event pattern

Specification of the event or sequence of events or aggregation that you are interested in. An event pattern can include conditions and operators.

event template

Basic unit of monitoring in the correlator. An event template specifies the pattern that you want to act on. A simple application contains one or a few event templates. A more complex application can contain many event templates. Here is an example of the data that a particular event template might define:

- Instrument = IBM

- Bid Price > 93 and < 95

- Offer Price = *

- Bid Volume > 100000

- Offer Volume = *

.evt

File extension for files that contain events.

exception

An exception is an object that represents a runtime error that can be caught with a `try ... catch` statement. In EPL, `Exception` is a reference type in the `com.apama.exceptions` namespace. See "Exception handling" in *Developing Apama Applications*.

listener

See and .

lot

The items produced by a single activation of a stream query. Like an auction lot, a stream query lot can contain one or more items.

MemoryStore

The MemoryStore provides an in-memory, table-based, data storage abstraction within a correlator. All EPL code running in a correlator in any context can access the data stored by the MemoryStore. In other words, all EPL monitors running in a correlator have access to the same data. The Apama MemoryStore can also be used in a distributed fashion to provide access to data stored in a MemoryStore to applications running in a cluster of multiple correlators.

method

There are two kinds of built-in methods: type methods and instance methods. Type methods are associated with types. Instance methods are associated with values. Built-in methods are treated exactly the same as user-defined actions. See .

.mon

File extension for EPL files.

monitor

A monitor contains event monitoring patterns and the responses to take when the monitor's listeners detect those patterns. You use EPL to define a monitor.

MonitorScript

EPL is the new name for MonitorScript. Within the product, both EPL and MonitorScript are used and should be treated as synonymous. EPL or MonitorScript is the Apama event-based scripting language that is an interface to the correlator.

optional

An `optional` is a value that contains either a value (of some EPL type), or is empty and thus has no value. This is useful for mapping to `null` values in other languages such as Java, or for data which may not be present in some circumstances.

partitioning

A strategy to scale Apama by deploying multiple correlator processes to spread the workload across several processors and/or machines. A correlator can be used to partition incoming events, sending them to different correlators based on rules specific to your partitioning strategy.

Software AG Designer

Eclipse-based GUI. When Apama is installed with Software AG Designer, you can use it for managing Apama projects, developing EPL files, and running Apama applications in test environments.

stack trace element

A stack trace element is an object that describes an entry in the stack trace. A `com.apama.exceptions.Exception` object contains a sequence of stack trace elements that show where an exception was first thrown and the calls that lead to that exception. In EPL, `com.apama.exceptions.StackTraceElement` is a reference type. See "Exception handling" in *Developing Apama Applications*.

static action

A static action can only be declared inside an event type. It does not apply to a specific instance of an event.

stream

A conduit or channel through which items flow. An item can be an event, a `location` type or a simple type (`boolean`, `decimal`, `float`, `integer`, or `string`). The set of items flowing through the

stream is often referred to as "a stream of items" and so, here, a stream represents an ordered sequence of items over time. A stream transports items of only one type. Streams are internal to a monitor.

stream listener

A construct that continuously watches for items from a stream and invokes the listener code block each time new items are available.

stream network

A network of stream source templates, streams, stream queries, and stream listeners. The upstream elements in the stream network feed the downstream elements to generate derived, added-value items.

stream query

A query that the correlator applies continuously to one or two streams. The output of a stream query is one continuous stream of derived items.

stream source template

An event template preceded by the `all` keyword. It uses no other event operators. A stream source template creates a stream that contains events that match the event template.

window

When working with streams, a window is a dynamic portion of the items flowing through a stream. A window identifies which items a stream query is currently processing.