Introduction to Apama

Version 10.11.3

April 2022

APAMA

This document applies to Apama 10.11.3 and to all subsequent releases.

Specifications contained herein are subject to change and these changes will be reported in subsequent release notes or new editions.

Document ID: PAM-INTRO-10113-20220411

Table of Contents

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:

- **Windows.** Select **Start > All Programs > Software AG > Tools > Apama *n.n* > Apama Documentation *n.n***. Note that **Software AG** is the default group name that can be changed during the installation.
- **UNIX.** 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 and is intended for use with other Software AG installation guides such as *Using Software AG Installer*.
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 different technologies for developing Apama applications: EPL monitors, Apama queries, and Java. You can use one or several of these technologies 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.

Title	Description
Building and Using Apama Dashboards	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 to one or more correlators by means of a dashboard data server or display server.
Deploying and Managing Apama Applications	Describes how to deploy components with Software AG Command Central, how to deploy and manage queries, and 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”.

Product Training

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

Tech Community

You can collaborate with Software AG experts on our Tech Community website at https://techcommunity.softwareag.com. From here you can, for example:

- 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://hub.docker.com/publishers/softwareag and discover additional Software AG resources.

Product Support

Support for Software AG products is provided to licensed customers via our Empower Portal at https://empower.softwareag.com. Many services on this portal require that you have an account. If you do not yet have one, you can request it at https://empower.softwareag.com/register. Once you have an account, you can, for example:

- 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.
- Look at the Apama demos in Software AG Designer. Click **Demos** under the **Apama** heading on the above-mentioned Welcome page.
- Use the skills you learned in the tutorials to try modifying the demos as suggested in their readme files.

There are several approaches for developing Apama applications:

- **EPL.** Apama's Event Processing Language (EPL) is designed for developing event processing applications. This approach is for programmers who need a powerful event processing language.
- **Apama queries.** Apama queries are useful when you want to monitor incoming events that provide information updates about a very large set of real-world entities such as credit cards, bank accounts, cell phones. Typically, you want to independently examine the set of events associated with each entity, that is, all events related to a particular credit card account, bank account, or cell phone. A query application operates on a huge number of independent sets with a relatively small number of events in each set.
- **Apama in-process API for Java (JMon).** Apama's JMon interface lets programmers use the industry standard Java programming language to develop event processing applications.

  Note:
  Keep in mind that this approach is less powerful and therefore not really recommended.

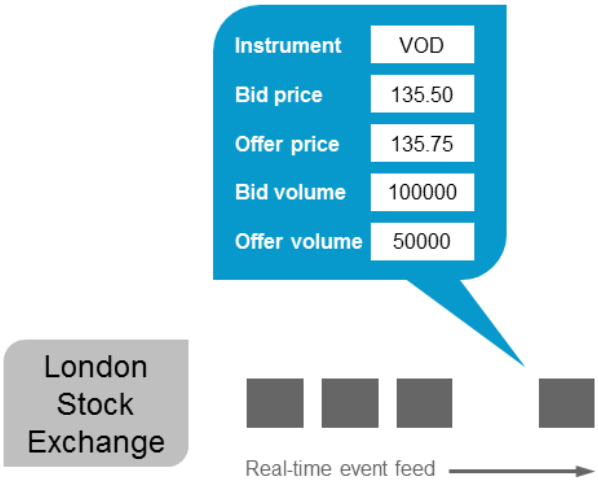
Depending on what you are trying to accomplish, you can use as many approaches as required in a single Apama application.

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 bid price for Vodafone's stock on the London Stock Exchange.

Events are collections of attribute-value pairs that describe a change in an object. For example, the figure below shows stock quote events. Each stock quote has a number of attributes, including current bid price, current offer price, and current volumes. In the figure, the highlighted event shows the latest quote for Vodafone stock.



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 multi- dimensional types, in that a search to find an event of interest might involve searching across several of the event fields.

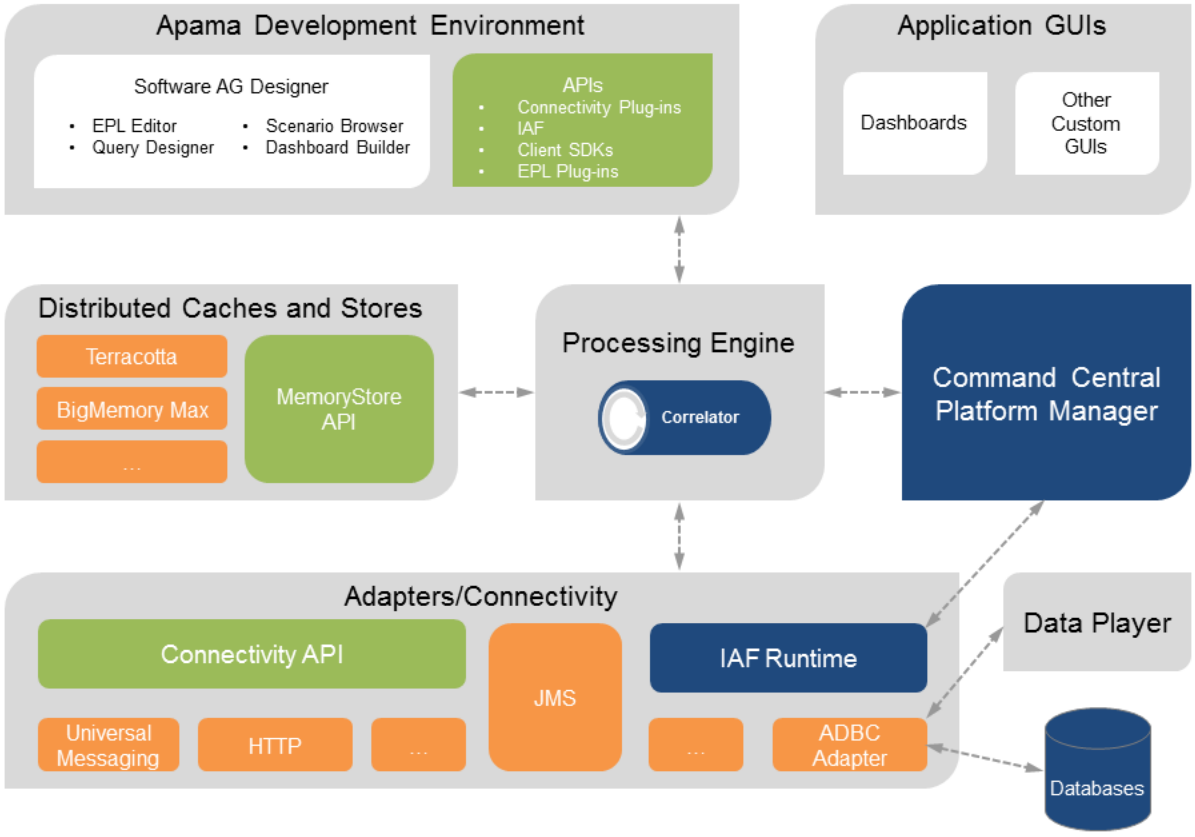
Rather than executing a sequence of activities at some defined point, an event-based system waits and responds appropriately to an asynchronous signal as soon as it happens. In this way, the response is as immediate (or real-time) as possible.

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.
- Integration Adapter Framework (IAF), which provides easy integration to external event source and systems.

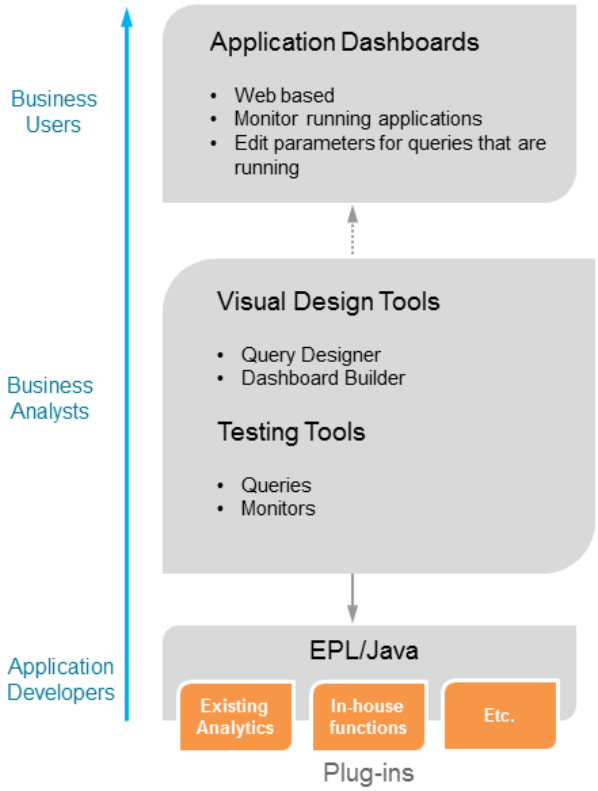
  Note:
  The IAF architecture is superseded by connectivity plug-ins. Therefore, Software AG strongly recommends choosing connectivity plug-ins over the IAF when creating new adapters and connectivity.
- Sophisticated analytics with native support for temporal arguments.
- Sub-second response to detected events and patterns of interest.
- Highly scalable, patented, event-driven architecture, supporting tens of thousands of concurrent scenarios.
- Integrated tools for creating visually appealing user dashboards.
- 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:



Understanding the different user viewpoints

Apama has been designed for a range of users. The figure below shows the spectrum of users from application developers to business analysts to pure business users. Apama provides different facilities for each of these classes of user. After the initial design is set for an Apama application, multiple users can work concurrently to implement the design.



Application developers can make use of the full set of APIs and technologies within the Apama architecture to create sophisticated, custom, CEP solutions. Using Software AG Designer, they can create applications directly in EPL or Java. They can extend the capabilities of the Apama correlator with their own in-house analytic routines. Using the connectivity plug-in API or the Integration Adapter Framework (IAF), they can integrate with a new data service by developing a new adapter if one that can be plugged in does not already exist. They can also take advantage of low-level APIs for building custom client user interfaces in C, C++, Java and .NET.

Business analysts are provided with GUI tools (Query Designer, Dashboard Builder) to enable the creation of queries and dashboards without having to write code. A query is a self-contained processing unit suitable for applications where the incoming events provide information updates about a very large set of real-world entities. A query can be an application in its own right, or part of a bigger application. Query Designer provides features for creating reusable application components (parameterized queries).

Thus, there are several approaches to developing Apama applications. Your development team can use one, two or all three in an Apama application:

- **EPL.** Apama's native event processing language.
- **Queries.** Use EPL and the Query Designer GUI to create Apama query applications.
- **Java.** Apama provides an in-process API for Java (called JMon) for processing events.

Pure business users are often only interested in the end-game application. The output of the Dashboard Builder GUI provides an immediately usable application for this purpose.

About Apama license files

Software AG supplies you with an Apama license file. Refer to the licensing terms specified in your software contract for any additional legal restrictions that may be imposed on your use of Apama.

A license file is required for the full functionality of Apama. The Software AG Installer will ask for it during the installation. See "License file" in *Installing Apama* for further information.

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 17.
- 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 have 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/guides/apama/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 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.

- The 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 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 and/or Apama queries that specify the events or patterns of events that interest you. These specifications are the logical equivalent of database queries. After you load monitors and /or Apama queries 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 and queries operating simultaneously. Each can have its own logic for monitoring the event streams, seeking out patterns and, upon detection, triggering specified actions.

The correlator supports two main programming languages: EPL and Java. 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.

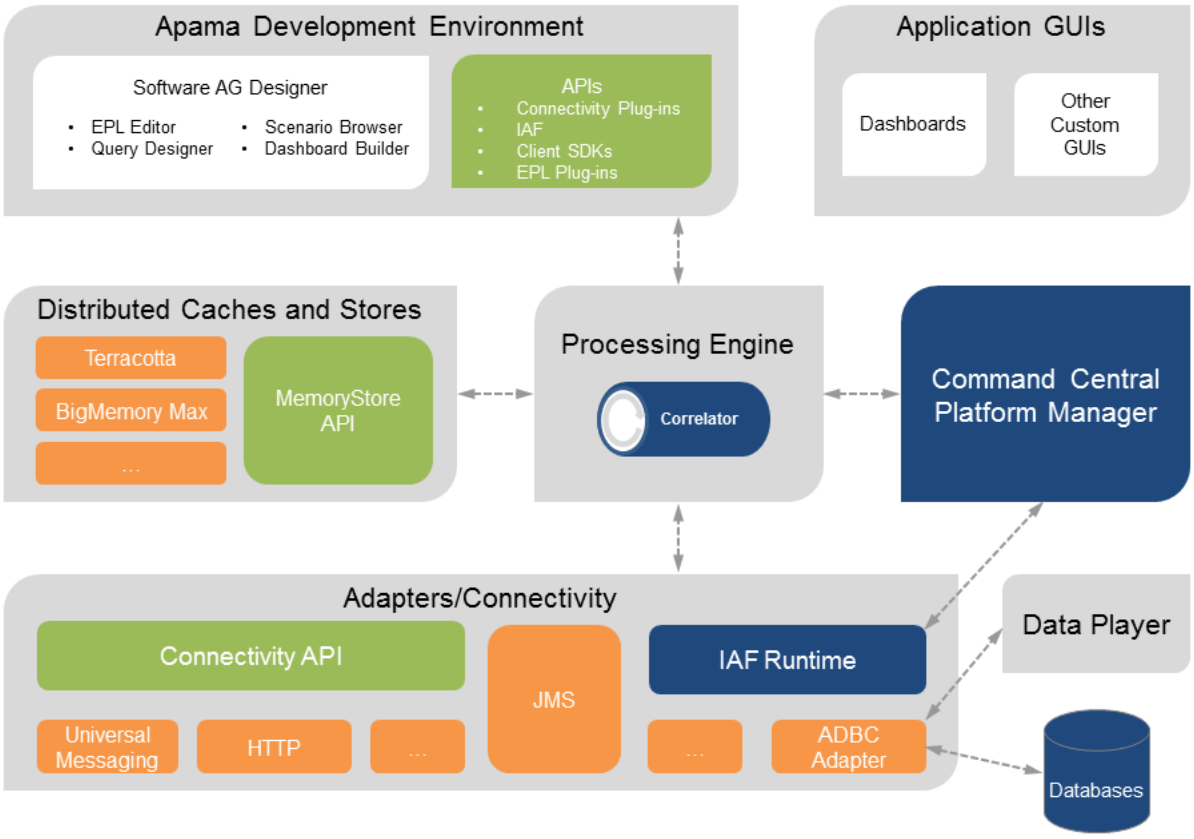
Messages on a variety of transports, such as an Enterprise Service Bus (ESB), carry events to and from correlators. Apama connectivity plug-ins and adapters translate application-specific data into Apama application event formats that the correlator can process. For example, Apama trading systems integrate with various exchanges by means of adapters that translate between Apama and market data feeds or order management protocols. For more information, see "How Apama integrates with external data sources" on page 21.

Apama's architecture also provides tools for creating dashboards that let you manage your event processing scenarios. You can use Apama dashboards to start, stop, parameterize, and monitor event processing from client applications.

The Apama ADBC (Apama Database Connector) adapter provides a mechanism to capture and replay event streams from JDBC/ODBC-compliant third-party databases. Together, the ADBC standard adapters and Apama's Data Player in Software AG Designer let you analyze the actual performance of applications already in production, and also investigate the likely behavior of Apama applications prior to deployment.

Apama components can be connected to each other by executing the Apama `engine_connect` tool with specification of an explicit point-to-point connection or by using Software AG's Universal Messaging message bus.

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.
- Implement Apama Integration Adapter Framework (IAF) adapters.
- Develop custom client applications with Apama APIs for Java, .NET, and C++.
- Create applications that use correlator-integrated messaging for JMS.
- Use Software AG Digital Event Services to communicate with other Software AG products.
- 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 perform a similar role to IAF adapters: both allow plug-ins to transform and handle delivery of events. In most cases, we recommend using connectivity plug-ins instead of the IAF for new adapters. The reasons are:

- Connectivity plug-ins run inside the correlator process itself. This allows for simpler deployments with less moving pieces. It also avoids problems for handling cases where one of the IAF and correlator are restarted and the other is not, or communication problems (including latency) between them. Ensuring the correct startup order is also simpler (see "Sending and receiving events with connectivity plug-ins" in *Connecting Apama Applications to External Components*).
- Connectivity plug-ins have a richer data model for both messages and configuration. Connectivity plug-ins can be given events (including sub-events), sequences and dictionaries as map objects. The values within a map can be strings, integers, floats, lists or maps. The lists and maps can in turn contain any of these types (for example, a map can contain a list, where the list contains a map which again contains a list, and so on). This provides an easier to use API for handling nested events and other nested data structures, both in EPL events and in external data formats (such as JSON).
- Connectivity plug-ins allow multiple codecs to be used in combination, allowing for a modular approach to message transformation and greater re-use of codecs.
- Connectivity plug-ins provide for reliable messaging (at-least-once delivery). See "Using reliable transports" in *Connecting Apama Applications to External Components*.

Connectivity plug-ins also 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 IAF adapters to connect with external data sources

Apama's Integration Adapter Framework (IAF) provides bidirectional connectivity with event sources and with your environment.

Note:

The IAF architecture is superseded by connectivity plug-ins. Therefore, Software AG strongly recommends choosing connectivity plug-ins over the IAF when creating new adapters and connectivity.

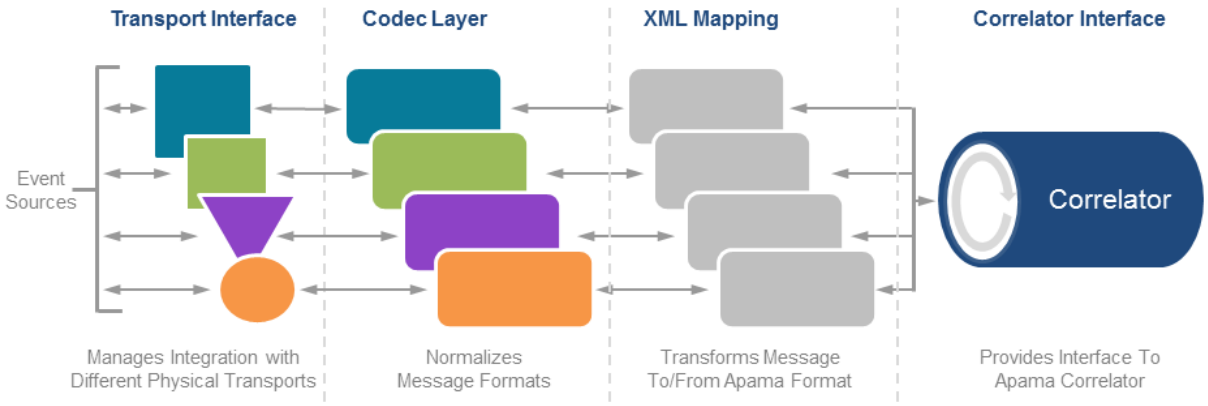
Apama adapters provide both connectivity and XML-based mapping between your application's data format and Apama's internal format. The purpose of an adapter is to translate events from a proprietary format into Apama events. This lets the correlator analyze those events. Also, an adapter converts Apama events into your proprietary source format. This lets Apama send the events to an external service.

Adapters allow a single Apama application to efficiently monitor and analyze disparate event types within a common event processing scenario. For example, the same scenario can process events relating to foreign exchange (FX) aggregation, smart order routing and cross-asset trading in capital markets or cold chain automation in supply chain applications.

Within the IAF, Apama offers a range of standard adapters for capital markets, infrastructure, and connectivity to data and messaging sources (see https://empower.softwareag.com/Products/default.asp), as well as APIs for building custom adapters.

The IAF is a server component that adapters plug into for runtime invocation. You can develop an adapter with the IAF adapter library, along with whatever specific connection APIs you need to connect to your data service. Each adapter is structured so that the mapping of parameters between the source format and Apama format can be configured dynamically through XML.

The following figure shows the bidirectional operation of an adapter.



Examples of types of adapters include:

- **Middleware messaging adapters.** Several middleware bus technologies are available on the market, including technologies by Tibco, IBM MQ Series, Vitria, webMethods, SeeBeyond and others. When the middleware you are using supports JMS, you can create applications that use correlator-integrated messaging for JMS in place of an adapter.

  Apama is able to interface with these technologies through an appropriate adapter. If the middleware bus offers publish and subscribe capabilities, then Apama can become a named endpoint like any other service. Apama is able to receive events from the bus and convert them, via an adapter, into Apama events for the correlator to process. An adapter can convert any events emitted by a correlator back into the native bus format.

- **Database adapters.** Apama is able to connect to databases for a number of purposes, including searching historical state or storing key events as an audit trail in the corporate database. Most popular databases support a standard access protocol, such as ODBC or JDBC. The Apama Database Connector (ADBC) provides ODBC and JDBC adapters that use these standard access protocols to connect to your database.
- **Custom real-time feed adapters.** A number of companies provide real-time content as information feeds. Examples in the finance industry include Reuters, who provides a variety of stock and news feeds, and GLTrade, who provides bidirectional access to a variety of the world's equities and derivatives exchanges. Many such companies use custom communications protocols to provide their data. However, Apama adapters have been easily developed for these and other bidirectional data services.

For detailed information, see "The Integration Adapter Framework" 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 dashboard, 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 Software AG Digital Event Services to communicate with other Software AG products

Software AG Digital Event Services is a messaging system for communicating between different Software AG products using events. Digital Event Services allows event definitions to be converted between a product's internal event or document definition to digital event types and vice versa, so participating products can share a set of event definitions. When you develop Apama applications that make use of Digital Event Services, the translation between digital event type definitions and Apama event types is done automatically. When digital events are sent to or received from Digital Event Services, they are converted to or from Apama events.

For detailed information, see "The Digital Event Services Transport Connectivity Plug-in" 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 a connectivity plug-in, the Cumulocity IoT transport, which allows you to communicate with the IoT devices connected to Cumulocity IoT. For example, you can receive events from the devices and send operations to the devices.

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, an extensible integration framework and graphically-rich dashboards. 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 32.

Description of event processing languages

Apama provides developers with two language models for building event-based applications:

- EPL, which is Apama's native event processing language
- Apama (in-process) API for Java (JMon)

This section gives you a flavor for how these languages process events. You can find complete information in *Developing Apama Applications*.

Introduction to Apama EPL

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, clients and the IAF 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)
```

There are two basic EPL structures called monitors and queries.

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.

Apama queries

An Apama query does the following:

- **Operates on only specified input events.** You can specify one or more event types. For each event type, you can filter event content so that the query operates on only certain instances of that event.
- Partitions input events according to their keys — Based on the values of selected fields in incoming events, the correlator segregates events into many separate partitions. Partitions typically relate to real-world entities that you are monitoring such as bank accounts, cell phones, or subscriptions. For example, an automated bank machine associates an account number with every transaction. You can define a query that partitions `Withdrawal` events based on their account number. Each partition could contain the `Withdrawal` events for one account. This lets you look for withdrawal patterns that look suspicious.

  Typically, a query application operates on a huge number of partitions with a relatively small number of events in each partition. Each partition is identified by a unique key value, such as an account number.
- **Watches for the event pattern of interest across all partitions.** An event pattern can define a sequence of events as well as conditions that determine whether there is a match. A condition can be a filter that specifies a Boolean expression that must evaluate to `true` for there to be a match, a time constraint that requires some or all elements in the pattern to occur within a given time period, or an exclusion, which is an event whose presence prevents a match.
- **Executes specified actions when a pattern match is found.** Actions can send events. This is how a query can communicate with other queries, with monitor instances, and with external system elements in a deployment, such as adapters, correlators, or other deployed processes.
- **Optionally uses parameters.** When a query has no parameters, a single instance of the query is automatically created when the query is loaded into a correlator. If one or more parameters are defined for a query then when the query is loaded into a correlator, no instances are created until you specify parameter values.

The following simple query example illustrates these concepts:

```
query ImprobableWithdrawalLocations {
   parameters {
      float period;
   }
   inputs {
      Withdrawal(value>500) key cardNumber within period;
   }
```

```
   find Withdrawal as w1 -> Withdrawal as w2
      where w2.country != w1.country {
      log "Suspicious withdrawal: " + w2.toString() at INFO;
   }
}
```

The optional `parameters` block in a query definition specifies parameters for which you must supply values so that an instance of the query (a parameterization) can be created. A query that defines parameters functions as a template for multiple parameterizations. Each parameterization of the simple query above would watch for the identified `Withdrawal` events for a different time period.

The `inputs` block of a query definition identifies the events that the query operates on. The example query operates only those `Withdrawal` events whose `value` field is greater than `500` and that arrived within the time range specified by the value of the `period` parameter. You can also specify that no more than a particular number of events can be in each partition at a given moment.

In the example, the `Withdrawal` input definition specifies the `cardNumber` field as the key. The query partitions incoming `Withdrawal` events according to their card numbers.

The `find` statement specifies the pattern you are looking for. In the example, the pattern of interest is a `Withdrawal` event followed by another `Withdrawal` event where the `country` fields for the two events are different. Since a query operates on the events in each partition independently of the other partitions, this pattern suggests a suspicious transaction.

Finally, when a query finds a match it executes the statements in its `find` block. In the example, the query logs a message that contains the `Withdrawal` event that triggered the match.

See also "Understanding queries" on page 41 and "Architectural comparison of queries and monitors" on page 43.

Introduction to Apama in-process API for Java (JMon)

EPL was designed specifically for event processing. However, some organizations and individuals prefer to use a mainstream programming language, such as Java. Consequently, Apama has made the features of the correlator available in Java.

The correlator uses its embedded Java virtual machine (JVM) to execute JMon monitors. The following Java code defines the `StockTick` event type.

```
import com.apama.jmon.Event;

public class StockTick extends Event {
   public String symbol;
   public double price;
   public double volume;

   //No argument constructor
   public StockTick() {
      this("",0,0);
   }

   //Constructor
   public StockTick(String name, double price, double volume) {
      this.name = name;
```

```
      this.price = price;
      this.volume = volume;
   }
}
```

In JMon, an event class definition must include the following:

- A set of public variables to hold the event's fields
- A no-arguments constructor
- A parameterized constructor

While this is not as concise as EPL, these are familiar Java conventions.

The following code defines a JMon monitor that listens for any IBM stock tick events with a price that is greater than `75.5`. The `onLoad()` method creates an event expression object, which receives an Apama event string. This string represents the event to listen for. Also, the `PriceCheck` class implements the `MatchListener` class, which provides a `match()` method to be invoked if the correlator finds a match. This is passed to the event expression object as well.

```
import com.apama.jmon.*;
public class PriceCheck implements Monitor, MatchListener {
   public PriceCheck() {}
   public void onLoad() {
      EventExpression eventexpr =
         new EventExpression("StockTick(\"IBM\",>75.5,*)");
      eventexpr.addMatchListener(this);
   }
   public void match(MatchEvent event) {
      System.out.println("Pattern detected");
   }
}
```

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 Query Designer

Apama's Query Designer editor, which runs in Software AG Designer, provides a graphical environment that complements Apama's event processing language. You use Query Designer to define and update Apama queries. An Apama query monitors a very large number of real-world entities and processes events on a per-entity basis, for example, all events related to one credit card account.

Query Designer provides graphical tools for specifying:

- **Inputs a query operates on.** For each input, you specify the event type and a partition key field. You can also specify a filter, a time constraint, and a maximum number of events to operate on in each partition.
- **Parameters** For each parameter you add, you specify a name and a type, which must be one of `integer`, `float`, `string`, or `boolean`.
- **Event pattern of interest.** After you add an event type as an input to a query, you can drag that event type on to a canvas where you graphically define the event pattern you are interested in.
- **Actions.** Define one or more actions to be executed when a match is found.
- **Conditions.** Add a filter, time constraint, or exclusion (an event that prevents a match) to the event pattern of interest.
- **Aggregates.** Find data based on many sets of events.

Query Designer is intended for business users who may not be familiar with EPL.

See "Adding query files to projects" in *Using Apama with Software AG Designer*.

Description of Dashboard Builder and Dashboard Viewer

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*.

Note:
This documentation refers to using the dashboard components provided with Apama. If you are using MashZone NextGen instead to visualize your data from Apama, refer to the MashZone NextGen documentation.

Description of client development kits

Apama is highly extensible with a range of APIs provided at the dashboard, 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

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

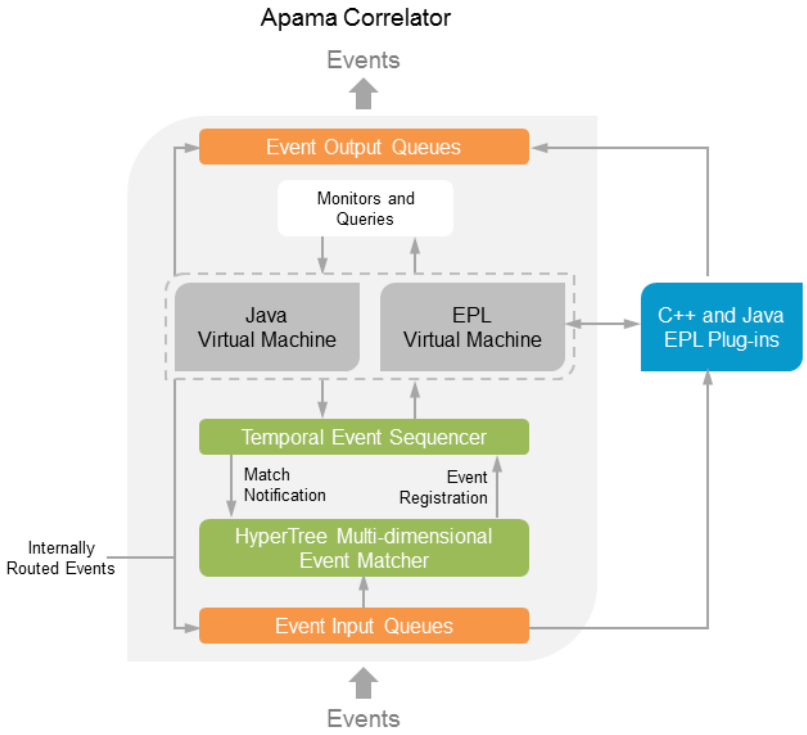
Data Player provides analysis tools for the Apama environment. It enables Apama users to investigate the likely behavior of Apama applications prior to deployment, as well as analyze the actual performance of those applications already in production.

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 and queries identify event patterns of interest and the responses to take if those patterns are detected. You can use EPL to write monitors and queries directly. You can use JMon to write monitors directly. Apama uses the Software AG Designer development environment for writing source code for monitors and queries, and provides a graphical editor for defining queries (Query Designer). When you use Query Designer, the query is translated into a monitor that the correlator can execute.

The correlator does not just execute loaded monitors and queries 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 and queries. The in-built virtual machines execute only the sequential analytic or action parts of the monitors and queries.

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 a stock market event might have values such as the following:

  - Instrument: `IBM`
  - Bid Price: `93.0 <- -> 94.5`
  - Offer Price: `*`

- Bid Volume: `>10000`
- Offer Volume: `*`

This event template expresses a multi-dimensional search over stock market events. The template will match any event about stock IBM, which has a bid price between 93.0 and 94.5 and a bid volume greater than 100000. The offer price and volume are irrelevant to this search and so wildcards are 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 or JMon, 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 either EPL or Java bytecode. 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.

- **Queries**

  Queries provide a higher level, more declarative mechanism for detecting event patterns. Unlike monitors, they also support automatically storing their state in a distributed cache such as Terracotta's TCStore. TCStore allows queries to transparently and elastically scale out with

the support of a JMS message bus such as Software AG's Universal Messaging. The storage size is thus limited by the distributed cache, which can exceed the memory size of a single host machine.

- **Event input queue**

  External interfaces, such as adapters and 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.

- **Java virtual machine**

  The Java virtual machine is a standard JVM that has been embedded in the correlator. Thus any standard Java code features are accessible from monitors. The Java virtual machine behaves exactly as the EPL virtual machine in that the detection of event patterns of interest invokes code fragments.

- **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 or the IAF, then an output event might represent an action on an external service. The connectivity plug-in or IAF 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 must be written in EPL. State in JMon monitors cannot be persistent. State in chunks, with a few exceptions, also cannot be persistent.

You program the correlator by injecting monitors that you write in EPL or JMon, or by injecting queries.

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:

- 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 and JMon provide the features needed to write applications that can perform CEP. The following example shows how EPL can concisely define event patterns and rules. While this example shows the implementation of an Apama monitor, an example that shows an implementation of an Apama query would also demonstrate complex event processing.

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 event processing languages" on page 26. As mentioned there, monitors are the basic program component that you inject into the correlator. You write monitors in EPL or JMon.

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 both EPL and JMon.)

The lifecycle of a monitor is as follows:

1. You use Software AG Designer or a correlator utility to inject the EPL or Java 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*.

Understanding queries

Apama queries allow business analysts and developers to create scalable applications to process events originating from very large populations of real-world entities. Scaling, both vertically (same machine) and horizontally (across multiple machines), is inherent in Apama query applications. Scaled-out deployments, involving multiple machines, will use distributed cache technology to maintain and share application state. This makes it easy to deploy across multiple servers, and keep the application running even if some servers are taken down for maintenance or fail.

Apama queries are designed to be easy to develop for both the business analyst and the application developer. Graphical tools to specify the application design and full round-trip engineering allows both the business analyst and the developer to work on the same queries. At the developer level, an Apama query is defined using the Apama event processing language, EPL.

Apama's visual Query Designer in Software AG Designer enables business analysts to easily create new queries and to view and review existing queries.

Use cases for queries

Apama queries are well suited to problems that:

- Map to a large set of partitions.
- Have continuous availability and/or scalability requirements.
- Do not require sub-millisecond latency.

Partitions may correspond to customer accounts, transactions being tracked, devices or some other entity. In a query application, the correlator processes the events in each partition independently of other partitions.

Advantages of Apama queries over Apama monitors:

- Platform provides active-active availability. That is, queries can be run in a cluster, where every node in the cluster contributes processing resources. The number of nodes can be changed dynamically without losing state.
- Scale out across multiple servers.
- Declarative pattern specification.
- Query evaluation is based purely on past event history. Other than events, queries have no state and so they behave uniformly over time.

Disadvantages of Apama queries compared to Apama monitors:

- Higher latency than monitors. Latency is of the order of milliseconds to seconds rather than microseconds to milliseconds. Exact values depend on the deployment and the types of events being processed.
- Apama monitors allow you to write custom and more powerful EPL applications that do not have the declarative and structural bounds that queries have.

To take advantage of the scalability and availability that the queries platform offers, the problem your application needs to solve should meet one or more of the following requirements:

- Different partitions for a given query must be completely independent. However, different queries can use different partition keys for the same event types. For example, one query may partition ATM withdrawals by `cardNumber`, and another by `atmId`.
- The average number of events in each window should be low. The recommendation is less than 50 events. For example, if ATM withdrawals are partitioned by `cardNumber` then a window that retains withdrawals for a three-day period is fine because the typical number of withdrawals per card is likely to be low. While it is possible to have hundreds of withdrawals for a single card number, that would be an exceptional case and probably indicative of suspicious behavior.
- Other than the history of events, no state is required. Queries do not provide for state to be stored. However, it is possible to mix monitors and queries in the same deployment.

- The time between events destined for the same partition would typically be long, that is, more than a few seconds between events.
- The exact ordering between events is not critical. A query may treat two events for the same partition that occur close in time as having occurred in an order that is different from the order in which they were sent.

Query application examples

Some examples of use cases for queries include:

- Customer relation management. Monitoring transactions between a retailer or service provider and individual customers. For example, queries can identify:
  - Transactions that are implausible and indicate fraudulent activity. See the ATM Fraud demo which is available from the Welcome page (see also "Demos and tutorials" in *Using Apama with Software AG Designer*).
  - Users who have not yet registered an optional account on their service provider's website. See the Unregistered_Users_Sample application which is available from the Welcome page. This is part of the Additional Samples.
  - Customers who may be interested in a particular retail offer.
- Tracking parcels. Monitoring parcels to determine when one is failing to progress through the distribution system for a certain amount of time, or is in danger of not arriving at its destination.

In all of these cases, the problem can be easily partitioned (by customer account or parcel), and the number of events per partition is likely to be low and spread out in time.

Architectural comparison of queries and monitors

In some ways, an Apama query is similar to an Apama monitor. Each operates as a self-contained event processing agent that communicates with other monitors and queries by sending and receiving events.

Note:
While Apama queries and Apama stream queries use similar terminology, they are different constructs. Apama queries can communicate with monitors, but Apama queries are not contained in monitors. Whereas Apama stream queries are defined and operate inside monitors.

One difference between a monitor and a query is the programming model for scaling. With monitors, the approach is procedural. A `spawn` statement is used to create new monitor instances. Typically, for each real-world entity, a separate monitor instance is used to handle the events relating to that entity. The developer has full control over what data is held where as well as the design of the solution architecture. With queries, the approach is declarative. A key is defined which is used to identify how the events are partitioned such that events from each real-world entity are handled separately. Also, queries can use a distributed Apama MemoryStore to share historical data between correlators. This allows query deployments to scale across several hosts, make the same data available to multiple correlators and provide availability should a correlator fail or be taken down for maintenance.

Another difference between monitors and queries is the way in which they handle the state, or event history. With monitors, each monitor instance holds the state, or event history, needed for its continuing processing. This state is held in memory, which allows high-performance processing over complex state. With queries, the only state is the event history, which is held separately from the query. The query is effectively stateless, which allows queries to easily scale across correlators.

Typically, a monitor instance operates on events that relate to a particular real-world entity. To operate on events related to another entity in the same set, the monitor typically spawns another instance. In contrast, the definition of a query specifies how to partition incoming events so that each set of events that relates to a particular real-world entity is in its own partition. The query operates on the events in each partition independently of every other partition.

The following table compares monitor variables with query parameters:

Monitor variables	Query parameters
Can store any complex state that the monitor requires.	Must be one of the following types: `boolean`, `decimal`, `float`, `integer`, `string`.
Can be updated by the monitor.	Can only be read by the query.
Are private to that monitor instance.	Are controlled by Scenario Service clients.

A monitor can subscribe to a channel to receive all events sent on that channel. A query cannot subscribe to a channel. However, running Apama queries automatically receive all events sent on the `com.apama.queries` channel as well as all events sent on the default channel. For example, monitors, adapters, and the `engine_send` utility can send events to the `com.apama.queries` channel.

Both monitors and queries can send events to a channel. In both monitors and queries, the `send` statement sends events to only those components that are connected to that correlator. For both monitors and queries, sending events to other correlators in the cluster requires connections created by the `engine_connect` utility or the use of Universal Messaging to connect the correlators to the same set of Universal Messaging channels.

In general, monitors follow a more imperative pattern while queries have more declarative clauses. For example, a monitor can use conditional `if ... else` statements to determine whether there is a match that triggers some processing. A query specifies `where`, `within`, and/or `without` clauses to define filters, time constraints, and exclusions, respectively, right in the event pattern. In general, this allows queries to be simpler than monitors.

Understanding dashboards

A DataView is a representation of application logic, but without any defined user interaction. You add a dashboard to a DataView to enable end-users to:

- Send an event to create a new DataView instance. This might include entering the initialization values for the DataView.
- Monitor the status of all DataView instances. For example, to see when a pattern has been detected, and some action taken.

- Manually intervene in the execution of a DataView instance. For example, to take some action in response to an alert.
- Send an event to deactivate a DataView instance.

In an Apama application, a dashboard is a real-time, business cockpit for controlling and receiving real-time updates from running DataViews. Deployed dashboards connect to one or more correlators through a dashboard data server. As the DataViews in a correlator run, and their variables or fields change, the correlator sends update events to all connected dashboards. When a dashboard receives an update event, it updates its display in real time to show the behavior of the DataView. User interactions with the dashboard, such as sending an event to create an instance of a DataView, result in control events that the dashboard data server sends to the correlator.

See "Introduction to Building Dashboard Clients" in *Building and Using Apama Dashboards*.

See "Making event type definitions available to monitors and queries" in *Developing Apama Applications*.

Alternatively, you can use the MemoryStore EPL plug-in in EPL applications. The MemoryStore creates DataViews for you.

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.
- Execute and examine the demonstration applications available from Software AG Designer. On the Welcome page, click **Demos** under the **Apama** heading. The demonstration applications are interactive. You can create instances of queries, set parameters for queries, and watch the queries execute. The demonstrations provide simple examples of what Apama can do and how you might interact with your Apama application.
- Examine sample code. Your Apama installation directory contains a `samples` directory that contains many examples of queries, monitors, JMon programs, 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 Query Designer to define a query.
- 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).
- Query files (`.qry` extension).
- Java files.
- Dashboard files (`.rtv` extension).
- Files that contain sample events (`.evt` extensions).
- C++, Java and .NET files that contain Apama client applications or EPL plug-ins.
- Adapters that provide the interface between your event sources and Apama.
- Image files for your dashboards.
- Text, HTML or XML files.

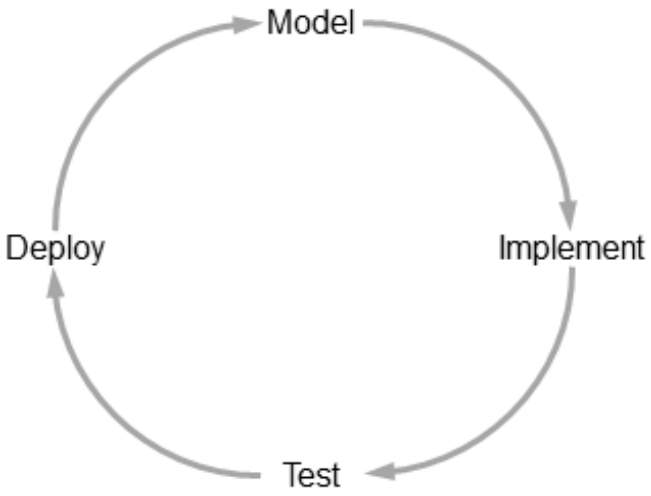
You can add and manage all of these files from your Apama project in Software AG Designer. In addition, Software AG Designer provides an EPL editor and a Java editor whose features include content assistance, auto-bracketing, templates for frequently entered constructs, and problem detection. After you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

If your project contains dashboards, Software AG Designer opens the Dashboard Builder when you double-click an `.rtv` file. You can also 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, adapters, event files, dashboards, 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:
   - Create queries with Apama's Query Designer in Software AG Designer.
   - Write EPL or JMon programs in Software AG Designer.
   - Develop Apama client applications.
   - Implement or develop adapters.
   - Create dashboards in Dashboard Builder.
   - 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 also use Apama's Data Player in Software AG Designer in conjunction with the ADBC adapter to analyze application behavior before, or after, deployment. You can automate testing through the use of command-line clients.
4. **Deploy**: Use Software AG Command Central to start and manage Apama components, including correlators. 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 create running instances of your queries and 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", "Debugging EPL Applications", and "Debugging JMon 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, events or queries. 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.

adapter

Software component that translates events from a non-Apama format to Apama format. This allows the correlator to analyze the event. An adapter plugs into the Apama Integration Adapter Framework (IAF) and injects events into the correlator. Adapters can be bidirectional, converting event formats in both directions.

aggregate function

A function that operates on all items in a 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 IAF 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 just as EPL files and JAR files containing JMon applications are injected.

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.

custom blocks

In Apama query `find` blocks, `%custom` blocks contain EPL code that you write.

dashboard

Business cockpit for controlling, receiving, and visualizing real-time updates from DataViews.

Dashboard Builder

GUI for creating and modifying dashboards.

dashboard data server

Process that mediates communication between dashboards and DataViews. The dashboard data server mediates correlator access for local deployments. It delivers raw data from which deployed dashboards construct the visualization objects that they display.

dashboard display server

Process that mediates communication between dashboards and DataViews. The dashboard display server mediates correlator access for simple thin-client, web-page deployments. It delivers already-constructed visualization objects in the form of image files and image maps.

Dashboard Viewer

Desktop application that supports local deployment of dashboards.

Data Player

Apama component in Software AG Designer that lets you retrieve events that pass through the correlator. You can use the Data Player to play back stored events and use the results to develop, test, and debug applications.

DataView

Table structure that contains event fields that you specify. In EPL applications, you create DataViews so that you can use the Dashboard Builder to create dashboards that let you interact with your running EPL application in the correlator.

EPL

The Apama Event Processing Language (EPL) is an event-based scripting language that is an interface to the correlator. Java is the other 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, dashboards, 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. Using Apama's Data Player in Software AG Designer, the collected events can be played back to analyze what happened or to test alternative strategies. The collected events can also 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 65.

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*.

IAF

Integration Adapter Framework.

Note:
The IAF architecture is superseded by connectivity plug-ins. Therefore, Software AG strongly recommends choosing connectivity plug-ins over the IAF when creating new adapters and connectivity.

Integration Adapter Framework (IAF)

Server component that adapters plug into for runtime invocation.

Note:
The IAF architecture is superseded by connectivity plug-ins. Therefore, Software AG strongly recommends choosing connectivity plug-ins over the IAF when creating new adapters and connectivity.

JMon

Apama in-process API for Java.

latest event

The latest event is the event that was most recently added to a query partition.

listener

See "event listener" on page 60 and "stream listener" on page 65.

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.

match set

For a query, this is the set of events that matches the specified pattern and that causes the statements in the query `find` block to be executed. A match set always includes the latest event.

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 "action" on page 57.

.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 can use EPL or Java 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. Java is the other 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.

parameterization

An Apama query that defines parameters is referred to as a parameterized query. An instance of a parameterized query is referred to as a parameterization.

parameters

An Apama query can define parameters and then refer to those parameters throughout the query definition. This enables a query definition to function as a template for multiple query instances, which are referred to as parameterizations.

partition

In a query, a partition contains a set of events that all have the same key value. One or more windows contain the events added to each partition.

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.

.qry

File extension for files that contain query definitions.

query

A self-contained processing unit. It partitions incoming events according to a key and then independently processes the events in each partition. Processing involves watching for an event pattern and then executing a block of procedural code when that pattern is found.

query aggregate

An event pattern in a query can aggregate event field values to find data based on many sets of events. Specify the `every` keyword in conjunction with the `select` and `having` clauses.

Query Designer

An Apama editor in Software AG Designer for writing queries.

query input definition

In a query, the `inputs` block defines one or more query input definitions. An input definition specifies an event type plus details that indicate how to partition incoming events. An input definition can also filter which events are operated on, and specify what state, or event history, is to be held.

query instance

When a query has no parameters, a single instance of the query is automatically created when the query is loaded into a correlator. This instance looks for match sets in all of this query's partitions. If one or more parameters are defined for a query, when the query is loaded into a correlator, no instances are created until a set of parameter values is specified. Apama's Scenario Service then creates an instance of that query using the specified parameter values and that instance is referred to as a parameterization.

query key

A query key identifies one or more fields in the events being operated on. Each input definition must specify the same key.

query window

For each input, a window contains the events that are current. The query operates on only current events.

range

In a query's `find` statement, a `within` clause and/or a `without` clause can specify the `between` keyword to define a range that restricts which part of the pattern the `within` or `without` clause applies to. The condition that the `between` clause is part of must occur in the range of identifiers specified in the `between` clause.

.rtv

File extension for dashboard view files.

simulation

A Data Player playback session that uses persisted event data for “what if” analysis. A simulation can test what would happen with modified data.

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

In a query, for each input, a window contains the events that are current. The query operates on only current events.

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.

within clause

In a query, a `within` clause sets the time period during which events in the match set must have been added to their windows. A pattern can specify zero, one, or more `within` clauses.

without clause

In a query, a `without` clause specifies event types, which must be specified in the query's `inputs` block, whose presence prevents a match. For example, if a potential match set contains three events, it can be a match only if a type specified in a `without` clause was not added to a window after the first event or before the third event. Any event type that can be used in the `find` pattern can be used in the `without` clause.