AI–IoT Internet of Things Drools-jBPM

The AI-IoT Drools-jBPM Design Architecture

Arduino Tron - Arduino ESP8266 MQTT Telemetry Transport (M2M) Machine-to-Machine

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Custom Software Development – Executive Order Corporation

www.executiveordercorp.com

Executive Order Corporation - We make Things Smart

Executive Order Corp is a leading provider of technology that helps global companies design, develop, deploy, and integrate software applications

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Arduino Tron AI-IoT-Internet of Things Drools-jBPM Development DOCUMENT REVISION HISTORY

List changes between each template release.
Increment Release Number by 1 is only between published versions.
(Update the Page Heading when published)

Version #	Date	Revised By	Description of Changes
0.5	3/04/2016	Steven Woodward	First Draft of AI-IoT Internet of Things.
1.02	7/07/2016	Steven Woodward	Add Rules modifications for Use Case requirements.
1.20	5/25/2018	Steven Woodward	Arduino Tron ESP8266 MQTT Telemetry Transport (M2M) Machine-to-Machine. AI-IoT Application using Drools-jBPM Expert System Engine Applications.

SUPPORTING DOCUMENTS

Document Number	Document Name Description
1	Business Requirements Document – Executive Order Document
2	SRS (System Requirements & Use-Cases) Document – EO Document
3	High-level Design Document – Executive Order Document
4	IF-SPECS Documents – Executive Order Document
5	Low Level Design – Application Development – Executive Order Document

About Executive Order Corporation

We make Things Smart

Executive Order Corp provides custom software built by software professionals. We specialize in IoT (Internet of Things), Desktop and web enabled IT solutions for small and large business enterprises. Our professional offerings span business and technology consulting, business application development, mobile messaging solutions, custom web design, Ecommerce development, web maintenance, website re-engineering, website optimization for search engine submission, internet marketing hosting solutions for enterprises, GPS, IoT (Internet of Things) and remote sensing services and development program planning and management.

TABLE OF CONTENTS

1 Arduino Tron AI-IoT Internet of Things with Artificial Intelligence

1.1 Internet of Things Artificial Intelligent Architecture

1.1.1 Internet of Things Artificial Intelligence Conclusion

- An inference model provides a conclusion reached on the basis of evidence and reasoning.

1.1.2 When IoT meets Artificial Intelligence

In the Internet of Things (IoT), as more and more devices and pieces of software interconnect, a great necessity arises for the systems that allow complex situations to be detected in a simple collaborative way by people and devices, and be able to react quickly upon detection of these situations.

IoT provides lots of telemetry and sensor data; however, the data points by themselves do not provide value unless they can be annualized and turned into actionable, contextualized information. Big data and data visualization techniques allow us to gain new insights by batch-processing and off-line analysis. Real-time sensor data analysis and decision-making is often done manually but to make it scalable, it is preferably automated. Artificial Intelligence (AI) provides us the framework and tools to go beyond trivial real-time decision and automation use cases for IoT.

With AI-IoT (Artificial Intelligence – Internet of Things) it is important to understand the difference and relationship between big data and real-time event reasoning, known as temporal reasoning. Big data analysis of sensor data retrieved from many IoT devices provides statistical information on particular components and data points. Decision making will allow deciding whether there is need for maintenance of one particular component. With temporal reasoning IoT sensors provide information that Drools AI is acted on immediately. In Drools AI-IoT, judging the impact avoidances of a vehicle and making course adjustments is AI temporal reasoning.

The AI-IoT rational agent is a central concept in artificial intelligence. An agent is something that perceives its environment through sensors and acts upon that environment via actuators, servos or motors. For example, a robot may rely on cameras as sensors and act on its environment via motors.

A rational agent is an agent that does ‘the right thing’. The right thing obviously depends on the performance criterion defined for an agent, but also on an agent’s prior knowledge of the environment, the sequence of observations the agent has made in the past and the choice of actions that an agent can perform. The AI BRMS Drools itself is the heart of the agent that computes and reasons based on the available data and its knowledge of the IoT sensors on the environment.

1.1.3 AI Patterns in STREAM or CLOUD Mode

Drools AI-IoT patterns behave different in STREAM mode when compared to CLOUD mode. In CLOUD mode, the engine assumes that all facts and events are known in advance (there is no concept of the flow of time) therefore, AI patterns are evaluated immediately.

When running in STREAM mode, patterns with temporal constraints require the engine to wait for an event to occur before activating the rule. The time period is automatically calculated by the engine and events are considered immutable state changes, the results of which will fire a rule.

Real-time sensor data analysis and decision-making is often done manually but to make it scalable, it is preferably automated. AI provides us the framework and tools to go beyond trivial real-time decision and automation use cases for IoT.

Executive Order Corp has developed both a CLOUD-based and a STREAM-based architecture that observes its environment via IoT defined sensors and act on its environment through AI BRMS Drools-jBPM software, arriving at conclusions reached on the basis of evidence and reasoning.

Executive Order Corp has developed an IoT platform that uses concepts of AI and applied those to the use case of smarter decision making in IoT.

“If a machine thinks, then a machine can do.” – Steven Woodward

“It’s not you interacting with the machine; it's the machine interacting with you.” – Steven Woodward

2 Arduino TronAI-IoT Internet of Things Tiered Design Architecture

2.1 AI-Artificial Intelligent IoT-Internet of Things

2.1.1 Advantages of an IoT Artificial Intelligent Rules Engine

The Internet of Things (IoT) is just the flowing of data between devices. It is inert and not as powerful as data flowing between intelligent things that can decide for themselves. As we have said in the opening "If a machine thinks, then a machine can do."

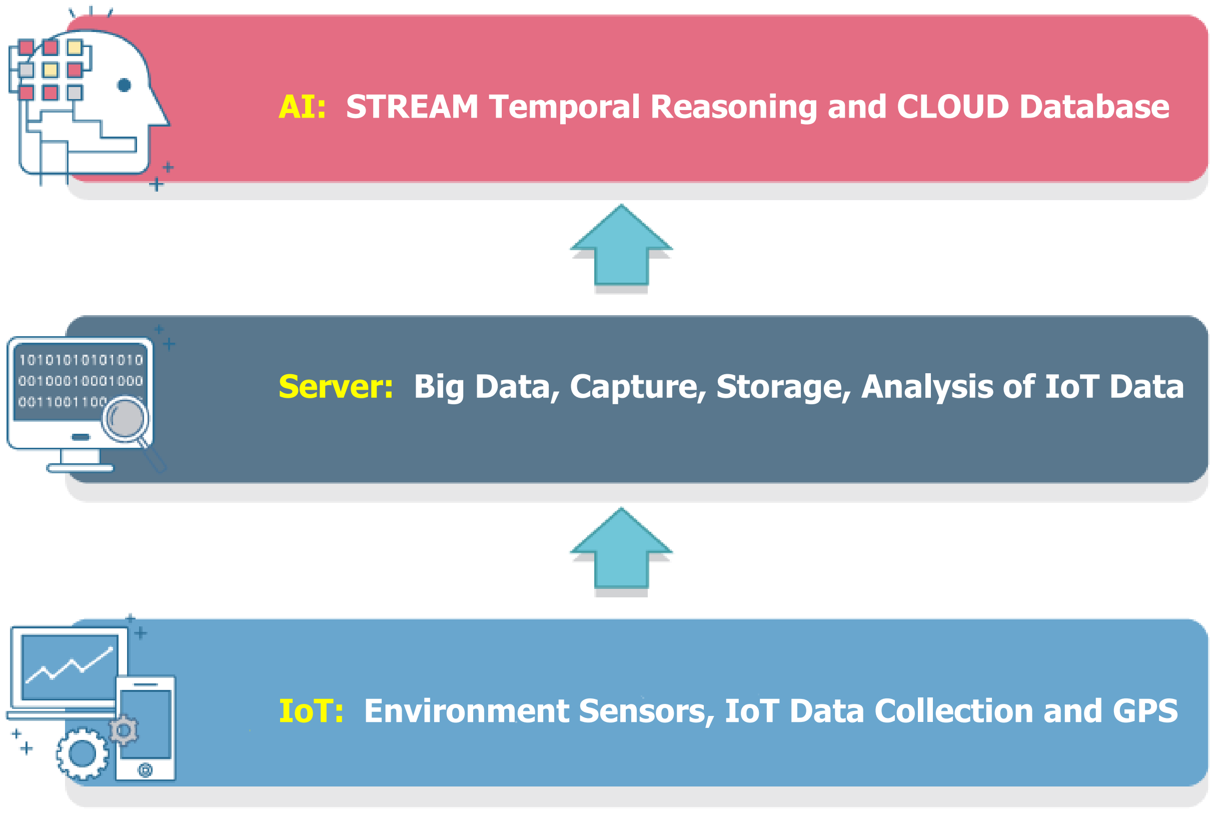
The billions of things that fall under the domain of IoT produce massive volumes of data, and this is where the greatest potential for AI-IoT (Artificial Intelligence – Internet of Things) lies. Tapping into those data streams will allow businesses, government and industry to improve manageability and ease of use for consumers, consumer safety and awareness, and enable quantum leaps in the level and quality of products and services.

The definition of Artificial Intelligence (AI) is the intelligence exhibited by machines or software. Arduino Tron AI-IoT is enabling what have previously been "dumb" devices to add new layers of functionality and access creating the basis for smart homes, smart cars, and smart manufacturing. It's not just about automatically turning on an air conditioner. The data collected, combined with Arduino Tron AI-IoT makes life easier with intelligent automation, predictive analytics and proactive intervention.

In an IoT scenario, AI can help companies in finding the groups of highly meaningful data and analyze trends/patterns for better decision making. Think about a car that never breaks down because each component is monitored and replaced before the MTBF (mean time between failures). The specific component failure is analyzed and each replacement component is an improvement on the last.

These are just a few promising applications of AI in IoT. The potential for highly individualized services are endless and will dramatically change the way people live. Executive Order Arduino Tron provides us the three tiered architecture to provide a complete AI-IoT system.

- **AI (Drools-JBPM):** AI-IoT the Internet of Things Drools-jBPM Expert System.
- **Server (EOSpy):** Sensor Processor live map GPS Tracking, Analysis of IoT Data
- **IoT (Arduino Tron):** Android Environment Sensors, IoT Data Collection and GPS


AI: STREAM Temporal Reasoning and CLOUD Database
Server: Big Data, Capture, Storage, Analysis of IoT Data
IoT: Environment Sensors, IoT Data Collection and GPS
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2.2 Arduino Tron IoT-Internet of Things Tiered Design Overview

2.2.1 AI (Drools-jBPM) Tier

Executive Order Corp has developed a three tiered approach to AI-IoT. The Arduino Tron AI tier is both a CLOUD-based and a STREAM-based architecture that observes its environment via IoT defined sensors and acts on its environment through AI BRMS Drools software, arriving at conclusions reached on the basis of evidence and reasoning.

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AI-IoT patterns behave differently in STREAM mode when compared to CLOUD mode. In CLOUD mode, the engine assumes that all facts and events are known in advance (there is no concept of the flow of time) therefore, AI patterns are evaluated immediately.

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Real-time sensor data analysis and decision-making is often done manually but to make it scalable it is preferably automated. AI provides us the framework and tools to go beyond trivial real-time decision and automation use cases for IoT.

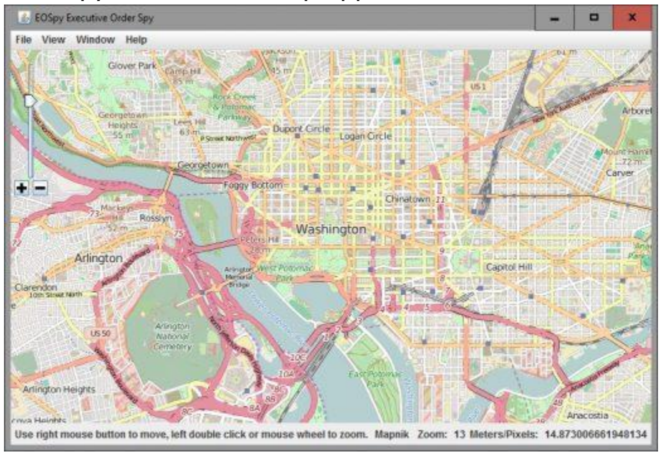
This is the Cognizant tier where the AI-IoT "Thinking" happens. Consider this: You have an intelligent refrigerator. It knows your milk is bad. It tells you when you open the door. Who cares? It notifies you in a meeting at work. So what? It knows that you are walking into a supermarket and reminds you inside to pick up milk. Now that's AI-IoT magic. As we said in the opening "It's not you interacting with the machine; it's the machine interacting with you."

2.2.2 EOSpy (Server) Tier

Executive Order Corp provides two middle tier server solutions. **EOSpy Windows,** a desktop application that can be installed on a windows computer. **EOSpy Server,** a web application (Web app) server application that delivers EOSpy information over the internet through a web browser. **EOSpy Mobile** is an Android mobile application that allows you to access EOSpy Server information remotely.

- **EOSpy-Executive Order Sensor Processor System for Windows**

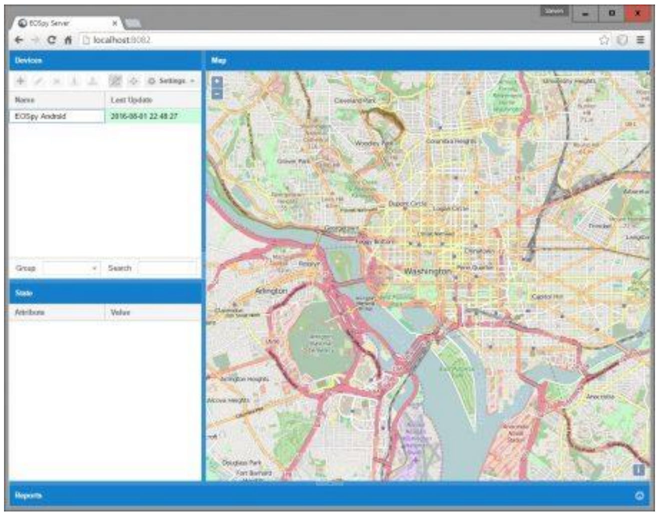
EOSpy windows desktop application main control window ties all location and environment monitoring information on one GPS map screen. With live map GPS tracking system that supports more than 90 GPS communication protocols and more than 800 models of GPS tracking devices from popular GPS vendors, EOSpy is designed to support as many tracking devices as possible. Check the EOSpy device list for supported GPS tracking devices. With EOSpy software, setup is a breeze. Just install the EOSpy software on your computer, enter the new GPS device unique identifier and you're ready to go. It is that easy to setup and use.



Use right mouse button to move, left double click or mouse wheel to zoom. Mapnik Zoom: 13 Meters/Pixels: 14.873006661948134

Executive Order Spy windows desktop application is designed for viewing "Real Time" live GPS tracking information over the internet/mobile cell network that does not require a monthly service subscription or fee. The EOSpy system provides information about any GPS tracking device directly on your computer. This unique product design allows live GPS tracking and surveillance without a costly monthly, third party subscription service.

- **EOSpy-Executive Order Sensor Processor System for Server**



EOSpy server web application (Web app) is a server application that delivers EOSpy GPS information over the internet through a web browser interface. The main control window ties all location and environment monitoring information on one GPS web browser map screen. EOSpy server is designed to support as many tracking devices as possible from popular GPS vendors. Check the EOSpy device list for supported GPS tracking devices. Setup is a breeze with EOSpy server software. Just install the EOSpy server software on your server computer or AWS, enter the new GPS device unique identifier and use any browser to connect to your web server.

Executive Order Spy server is a web application for viewing "Real Time" live GPS tracking information over the internet/mobile cell network that does not require a monthly service subscription or fee. The EOSpy server provides information about any GPS tracking device directly in your web browser. This unique product design allows live GPS tracking and surveillance without a costly monthly, third party subscription service.

- **EOSpy-Executive Order Sensor Processor System for Mobile**

EOSpy mobile GPS tracking system – An Android mobile version of EOSpy server. The mobile Android application allows you to use your mobile Android phone to monitor your GPS tracking device remotely.

EOSpy mobile is easy-to-use and helps you stay connected in "Real-Time" with your EOSpy GPS devices and IoT telemetry information. This provides seamless integration between your EOSpy server live-map GPS tracking devices and your mobile phone.

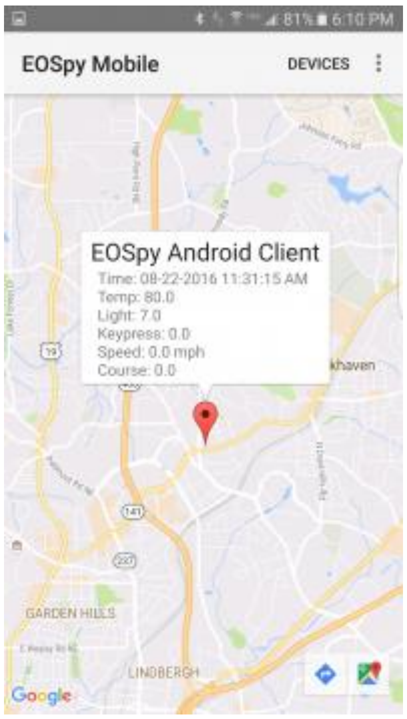
Connect to your EOSpy server – web application (Web app) is a server application that delivers EOSpy GPS information over the mobile interface. The main control window ties all location and environment monitoring information on one mobile GPS map screen. It is designed to support as many tracking devices as possible from popular GPS vendors.

Using EOSpy mobile app for viewing "Real Time" live GPS tracking information over the internet/mobile cell network does not require a monthly service subscription or fee. EOSpy mobile provides information about any GPS GSM tracking device directly on your Android Smart Phone.

EOSpy mobile monitors buildings, vehicles and people from anywhere in the world.

EOSpy mobile shows your GPS tracking devices on your Android phone map and receives ambient temperature, ambient light, and simple button press information on your GPS tracking device.

With the EOSpy mobile GPS tracking system you can stay connected and informed to what's important to you from your IoT devices. Additionally, the Arduino Tron - Arduino ESP8266 provides MQTT telemetry transport for (M2M) Machine-to-Machine and IoT.



EOSpy mobile can also receive IR object temperature, humidity sensor, pressure sensor, accelerometer, gyroscope, magnetometer, digital microphone, magnetic sensor, and EOSpy Mobile has Advanced Reverse Geocoding – Geocoding is the transformation process of addresses and places to coordinates and is sometimes called forward geocoding; whereas reverse geocoding uses geographic coordinates to find a description of the location, most typically a postal address or place name. EOSpy mobile will provide you with the address of each GPS tracking device.

EOSpy mobile – The GPS tracking automation and remote monitoring system is a complete package for business or office. Its wireless GPS tracking allows you to monitor your office, systems, personal property, and business from anywhere in the world. Receive remote information from any number of events like when an employee arrives on-site or where a vehicle is located.

EOSpy mobile advanced reverse geocoding – Geocoding is the transformation process of addresses and places to coordinates and is sometimes called forward geocoding; whereas reverse geocoding uses geographic coordinates to find a description of the location, most typically a postal address or place name. EOSpy will provide you with the address of each GPS tracking device.

2.2.3 IoT (Arduino Tron / EOSpy) Tier

EOSpy supports over 100 different communications protocols from popular vendors and more than 800 different models and devices. Additionally, EOSpy supports Android application development giving you an IoT platform to develop custom IoT Android applications and devices. EOSpy supports a very extensive IoT Tier layer providing both custom and off-the-shelf solutions. All of which is totally extensible to build your own custom IoT solution.

- **EOSpy Client**

Executive Order Spy Android Client app allows you to use your mobile phone as a GPS tracking device. It reports location and additional information to EOSpy at selected time intervals. The app also sends remote ambient light intensity, temperature and humidity information to the EOSpy live map server. Using an internet-connected or mobile cell network connected Android phone or device, streaming location and environment information is at your fingertips.

Remote streaming of additional information is possible like the following: accelerometer, magnetometer, gyroscope, IR temperature, barometer, and equipment status and condition. Monitor buildings, vehicles and people from anywhere in the world. Stay connected and informed to what's important to your company and business.

Executive Order Spy Client - The GPS tracking automation and remote monitoring system is a complete package for home or office. Its wireless GPS tracking allows you to monitor your office, systems, personal property and family from anywhere in the world. Receive information from any number of events like when an employee arrives on-site, where a vehicle is located, and even receive remote ambient light intensity, temperature, humidity and additional information.

With remote live GPS map tracking information you can monitor real-time data anywhere, anytime using your internet-connected computer or tablet. EOSpy supports more than 100 GPS communication protocols and more than 800 models of GPS tracking devices from popular GPS vendors.

- ***Custom Android Apps and Dedicated Devices***

For many commercial business applications, the desire is to use a device for a specific function without the distraction and security threats of an open ecosystem. Custom Android apps allow your business to harness the powerful capabilities of the Android operating system and tailor it to your specific needs. These dedicated device solutions can be custom mounted products or off-the-shelf handheld devices or purpose built devices.

The EOSpy Client Executive Order Spy Android Client app (name very long)is an excellent, proven, pre-build platform app that allows you to use a mobile Android device as a GPS tracking device. The EOSpy Android Client app provides a solid platform that your company can build its own custom dedicated app on using an internet-connected or mobile cell network connected Android device for location and environment information. The EOSpy Client provides a stable, proven, customizable application for your business to send telemetry information to your corporate or cloud computers.

- **EOSpy-TI Client**

EOSpy-TI wireless GPS tracking allows you to monitor your office, systems, personal property, and fleet from anywhere in the world. Receive remote information from any number of events like when an employee arrives on-site to where a vehicle is located. The SensorTag Reader will read all sensors from the TI-SensorTag Bluetooth LE device. EOSpy-TI will send GPS position and remote data for the following: ambient temperature, IR object temperature, humidity sensor, pressure sensor, ambient light, gyroscope, magnetometer, digital microphone, magnetic sensor, accelerometer, and simple button press, magnetometer and additional information.

Executive Order Spy Android Client app allows you to use your mobile phone as a GPS tracking and TI BLE SensorTag sensor device.

- **EOSpy GPS Tracking Devices**

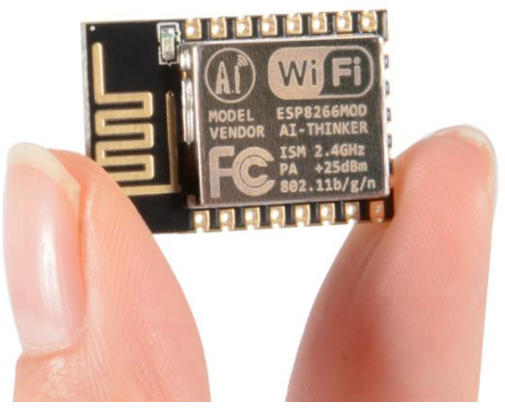
EOSpy is compatible with most popular GPS tracker devices and many companies make various off-the-shelf GPS tracking devices that can be purchased from a number of vendors.

These GPS tracker devices report location and additional information to the EOSpy server at selected time intervals. Using an internet-connected or mobile cell network, constant information is at your fingertips.

EOSpy supports more than 100 GPS communication protocols and more than 800 models of GPS Tracking Devices from popular GPS vendors. It is designed to support as many tracking devices as possible. Devices that can be installed in your vehicle, miniature devices that can be carried, GPS watches, GPS dog collars and property tracking/locators, these GPS Tracking Devices from a huge number of manufacturers are compatible with the EOSpy GPS map system. An extensive list of GPS tracking devices and applications supported by EOSpy Server is available on the compatible devices EOSpy website. This list is the mini real-time GSM / GPRS / GPS trackers Executive Order Spy devices most commonly supported by the EOSpy GPS map system Server.

2.3 Arduino Tron – Micro ESP8266 WiFi NodeMCU MQTT

- **Arduino Tron – Smart Micro-Miniature IoT MQTT Devices**



Executive Order Corporation releases EOSpy (Executive Order Sensor Processor System) Arduino Tron for AI-IoT Internet of Things with Artificial Intelligence, jBPM and Drools Rules Inference AI Architecture for AT-ES Systems. Executive Order, we make **"Things Smart"**.

Arduino Tron – A miniature smart Arduino ESP8266 MQTT telemetry transport device. The Arduino Tron smart micro device is about the size of your thumb and can fit into the smallest spaces in your equipment. The Arduino Tron micro can send alerts on equipment failures, faults or service conditions. This keeps you in constant contact with your equipment, employees, assets & field equipment status providing you instant alerts and status conditions.

The Arduino Tron is built on the Arduino NodeMCU ESP8266 WiFi MQTT Telemetry Transport Machine-to-Machine (M2M) Internet of Things (IoT) device for IoT. The Arduino Tron AI-IoT Client transmits IoT data using WiFi to the Arduino Tron AI-IoT for Drools-jBPM engine MQTT alerts and processing.

Arduino Tron AI-IoT: AI-IoT Application using Drools-jBPM Expert System Engine for Arduino Tron and EOSpy AI-IoT Applications designed Arduino ESP8266 MQTT Telemetry Transport WiFi NodeMCU.

- **Custom Hardware from Prototype to Fabrication and Manufacturing**

A major driver in the **IoT** space is the "new hardware movement" where hardware development is becoming an agile process and looking much more like the software development process. New tools allow for hardware to be developed and shipped with much greater flexibility and with shorter timelines. Executive Order Corp can help your company with complete Electronic Manufacturing Services (EMS).

  - **Printed Circuit Board Design**
  - **Rapid Prototyping**
  - **Industrial Design**
  - **Manufacturing Specifications**
  - **Q/A Testing**
  - **Arduino MQTT (IoT) Software**

Executive Order Corp can custom design and build/program your **Arduino IoT** devices. Executive Order Corp Electronic Manufacturing Services (EMS) are provided by companies that design, assemble, produce, and test electronic components and printed circuit board (PCB) assemblies for Original Equipment Manufacturers (OEMs).

Executive Order Corp EMS service provides a variety of manufacturing services including design, assembly, and testing. Our EMS service is complete from planning, design, develop, to production and board testing. We source the components from a trusted distributor, assemble and test the products.

- **The Internet of Things (IoT)**

At Executive Order Corp we are uniquely positioned with the hardware and software experience to help your business capitalize on the **IoT** revolution. We help your company with **IoT.**

  - **Physical Engineering**: Electrical, Component and Mechanical
  - **Design**: Prototyping, Industrial design, UI / UX
  - **Manufacturing**: Design for Manufacturing, Supply Chain Management (SCM)
  - **Security**: Device, Software, Cloud, and Protocol Specific such as BLE 4.2
  - **Software**: Networking and Infrastructure, Embedded-Systems Programming, Big Data, Machine Learning, Servers, Cloud Computing, Arduino Apps and Web

"**Internet of Things**" is a set of technology that will gradually and sometimes almost imperceptibly begin to affect us in the coming years. Any specific device or application might be small, but the combination of sensor and devices will create significant long-term changes that can both make our lives easier and more informed. The Arduino ESP8266 ESP-01S WiFi Serial Transceiver Module with 4MB Flash for Arduino provides very inexpensive **IoT MQTT** Telemetry Transport platform.

IoT promises to provide "**smart**" environments (homes, cities, hospitals, schools, stores, offices, etc.) and smart products (cars, trucks, airplanes, trains, buildings, devices, etc.). But, the task of moving beyond "connected" to "smart" IoT devices is daunting. Moving beyond just collecting IoT data and transitioning to leveraging the new wealth of IoT data to improving the smart decision making is the key. Executive Order EOSpy / Arduino Tron AI-IoT will help these IoT devices, environments and products to self-monitor, self-diagnose and eventually, self-direct.

I tell people the key with AI-IoT is, "If a machine thinks, then a machine can do".
Also, "It's not you interacting with the machine, it's the machine interacting with you"

- **Arduino WiFi MQTT Sensors and IoT Devices**

Sensors provide the data you need to automate processes and gain visibility into your business operations. At Executive Order Corp we have extensive expertise in the Industrial Internet of Things (IIoT) and Machine to Machine (M2M) technology that can be what your company needs to increase efficiencies or disrupt business models. Additionally, you can add jBPM and Drools Rules AI-ES reasoning to your business models for "**Smart**" IoT device reasoning.

Arduino Tron WiFi provides remote streaming of the following additional information directly to the EOSpy live map server: ambient temperature, IR object temperature, humidity sensor, pressure sensor, ambient light, accelerometer, gyroscope, magnetometer, digital microphone, magnetic sensor, and simple button press, magnetometer and equipment status conditions. Monitor buildings, vehicles, and people from anywhere in the world. Stay connected and informed to what's important to your business.

- **Developing Embedded Systems**

Developing embedded systems and devices firmware requires the ability to work with both hardware and software, observe real-time constraints, account for new and custom designs, and configure or create new operating systems. Executive Order Corp offers a wide range of embedded design services that can transform an idea into a complete full product. This includes the devising of system architecture, board and firmware design, application software development, mechanical design, proto-typing, validation, regulatory certification and pilot production. Let our experienced professionals support your project and instill the highest level of confidence in your embedded system design.

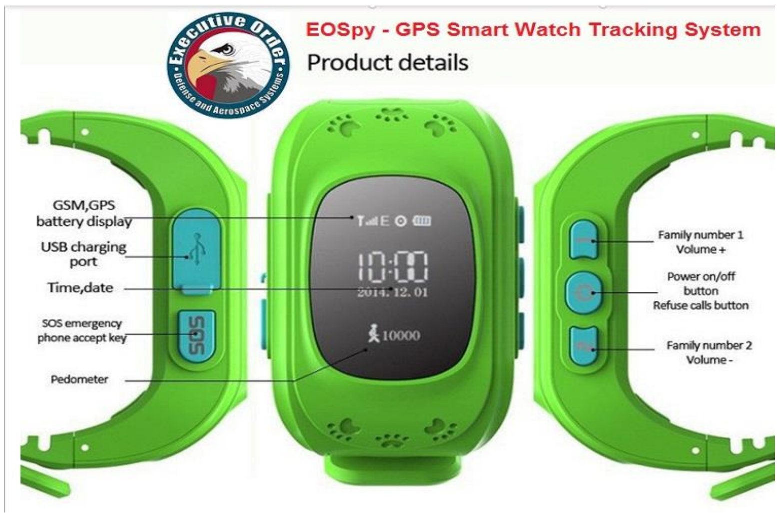
- **Custom Arduino Applications and Dedicated Devices**

For many commercial business applications, the desire is to use a device for a specific function without the distraction and security threats of an open ecosystem. Custom Arduino applications allow your business to harness the powerful capabilities of the Arduino system and tailor it to your specific needs. These dedicated device solutions can be custom mounted products or off-the-shelf handheld devices.

The Arduino Tron is an excellent, proven, pre-build, platform application that allows you to use a mobile Arduino MQTT telemetry transport device. It can report location and additional information to EOSpy at selected time intervals. The Arduino Tron application provides a solid platform that your company can build its own custom dedicated application on using an internet-connected or mobile cell phone network connected Arduino device for GPS location, environment, and condition or reporting device (board) error and status information remotely.

In addition to the Arduino NodeMCU sensors: light sensor, pressure sensor, temperature and humidity sensor, the Arduino NodeMCU can receive action commands from EOSpy/HTTP for 7 seg display, relay, buzzer, infrared emitter, LED, motor actuators, gate access, auditable speech, alarms, etc.

- **EOSpy Wearables**



EOSpy Workforce tracking - manage and protect your employees with personal GPS trackers.

Receive information from any number of events like when an employee arrives on-site, where an employee is located and even receive remote alert information.

EOSpy is ready to track employee time and location, from the time an employee arrives on-site until the time they leave.

EOSpy Workforce GPS time tracking adds great value to any organization with benefits for employers and managers. Locate employees in real-time and invoice with confidence with data to support client invoicing and confirmation on employee on-site location.

Wearable devices provide a new range of capabilities related to IoT. Some new functions that wearable IoT devices provide are related to identification, security, and GPS location. Consider an advanced IoT badge that includes biometric capabilities such as fingerprint activation. IoT badges can also include capabilities for location sensing, useful in emergencies to make sure everyone has successfully evacuated the building. An IoT wearable bracelet provides a more reliable indication of location since it is less likely to be left behind.

IoT wearable devices could automatically connect to devices around the home. Perhaps you have a preferred lighting level when watching TV. You could turn on the TV and your wearable device could help adjust the lighting level from the connected LED lights within the room. An intelligent house could support all these interactions automatically from your IoT wearable device.

AI-IoT Arduino Tron Sensor

The EOSPY AI-IoT Arduino Tron sensor software allows you to interface and send MQTT telemetry transport information from your external connected Arduino devices to the EOSpy server. The AI-IoT Arduino Tron server software uses a WiFi wireless transceiver interface to stream telemetry information to the EOSpy server for any control module sensors or remote control connected Arduino device.

AI-IoT Arduino Tron Server

The EOSPY AI-IoT Arduino Tron server software interface allows you to send commands with the EOSPY AI-IoT software to control external Arduino connected devices. The AI-IoT Arduino Tron server software uses a WiFi wireless transceiver interface to control and interact with module sensors and remote controls devices. You can control any device from the EOSpy AI-IoT Arduino Tron server software or stream any interface over the WiFi internet. With the EOSpy AI-IoT Arduino Tron server software you can automatically turn on lights, appliances, cameras, and lock/unlock doors from the Drools-jBPM expert system processing model.

Executive Order Corporation provides custom software and hardware development for Arduino MQTT, NodeMCU, (ESP8266 WiFi microcontroller), low cost, smart IoT, WI-FI enabled, Lua 5.1.4 devices.

The Executive Order Corp Arduino Tron - Arduino ESP8266 MQTT telemetry transport Machine-to-Machine (M2M) /Internet of Things software and Arduino Tron MQTT AI-IoT Client using EOSpy AI-IoT Drools-jBPM latest software can be download from the Github website.

Download Arduino Tron from: https://github.com/eodas/EOSpy

3 Arduino Tron AI-IoT Internet of Things Drools-jBPM Architecture

3.1 AI-IoT Internet of Things Rules Design Overview

3.1.1 Why use a Rule Engine jBPM for IoT Internet of Things?

Some frequently asked questions:

- When should you use a rule engine?
- What advantage does a rule engine have over hand coded "if...then" approaches?
- Why should you use a rule engine instead of a scripting framework, like BeanShell?

3.1.2 Advantages of a Rule Engine

Below summarizes the key business benefits for using Red Hat JBoss BRMS, a comprehensive platform for business rules management, business resource optimization and Complex Event Processing (CEP).

• Declarative Programming

Rule engines allow you to say "What to do", not "How to do it".

The key advantage of this point is that using rules can make it easy to express solutions to difficult problems and consequently have those solutions verified. Rules are much easier to read than code.

Rule systems are capable of solving very hard problems providing an explanation of how the solution was arrived at and why each "decision" along the way was made (not so easy with other Artificial Intelligent (AI) Systems like neural networks or the human brain).

• Logic and Data Separation

Your data is in your domain objects, the logic is in the rules. This is fundamentally breaking the OO coupling of data and logic, which can be an advantage or a disadvantage depending on your point of view. The upshot is that the logic can be much easier to maintain when there are changes in the future, as the logic is all laid out in rules. This can be especially true if the logic is cross-domain or multi-domain logic. Instead of the logic being spread across many domain objects or controllers, it can all be organized in one or more discrete rules files.

• Speed and Scalability

The Rete algorithm, the Leaps algorithm, and their descendants such as Drools' ReteOO provide very efficient ways of matching rule patterns to your domain object data. These are especially efficient when you have datasets that change in small portions as the rule engine can remember past matches. These algorithms are battle-proven.

• Centralization of Knowledge

By using rules you create a repository of knowledge (a knowledge base) which is executable. This means it's a single point of truth, for business policy, for instance. Ideally rules are so readable that they can also serve as documentation.

• Tool Integration

Tools such as Eclipse provide ways to edit and manage rules and get immediate feedback, validation and content assistance. Auditing and debugging tools are also available.

• Explanation Facility

Rule systems effectively provide an "explanation facility" by being able to log the decisions made by the rule engine along with why the decisions were made.

• Understandable Rules

By creating object models and, optionally, domain specific languages that model your problem domain you can set yourself up to write rules that are very close to natural language. They lend themselves to logic that is understandable to possibly nontechnical and domain experts.

3.2 IoT Internet of Things Solution Design Considerations

3.2.1 Design Methodology

The following key design methodologies are utilized in the IoT- AI application:

- **Business Rule Engines**

Provides a mechanism to define, deploy, execute, monitor and maintain the variety and complexity of decision logic that is used by operational systems within an organization. Most rules engines used by businesses are forward chaining, which can be further divided into two classes:

  - The first class processes so-called production/inference rules. These types of rules are used to represent behaviors of the type WHEN condition THEN action. For example, such a rule could answer the question: "Should the Car Move or is it BLOCKED?" by executing rules of the form "WHEN some-obstacle THEN Automobile.Status.BLOCKED".
  - The other type of rule engine processes so-called reaction/Event Condition Action rules. The reactive rule engines detect and react to incoming events and process event patterns. For example, a reactive rule engine could be used to alert when certain condition or failure happens 5 times within 30 minutes.

- **The IoT Rules**

Most of the rules used by STREAM IoT system are event declaration. To declare a fact type as an "event" all that is required is to assign the @role metadata tag to the fact type.

The @role metadata tag accepts two possible values:

- **Fact**: (this is the default) Declares that the type is to be handled as a regular fact. This would be a typical CLOUD type of rule.
- **Event**: Declares that the type is to be handled as an event. Every event has an associated timestamp assigned to it.

By default, the timestamp for a given event is read from the session clock and assigned to the event at the time the event is inserted into the working memory. All facts are static and stored in the IoT system production memory as rules or events. The facts that the inference engine matches against are kept in the working memory. Using the CEP pattern of processing the event driven architecture from the transaction database to the JBoss Drools/Fusion (CEP) the facts are inserted into the IoT working memory when the data collection/transaction occurs.

* Defining terms is not the goal of this guide and as so, let's adopt a loose definition that, although not formal, will allow us to proceed with a common understanding. So, in the scope of this guide: Event is a record of a significant change of state in the application domain at a given point in time. Events are immutable and can be embellished. A transaction is an event.

- **Event-Driven Architectures**

An Event-Driven Architecture (EDA) is a software architecture pattern promoting the production, detection, consumption of and reaction to events. Building applications and systems around an event-driven architecture allows these applications and systems to be constructed in a manner that facilitates more responsiveness because event-driven systems are, by design, more normalized to unpredictable and asynchronous environments.

Event processing is a method of tracking and analyzing (processing) streams of information (data) about things that happen (events), and deriving a conclusion from them. Complex event processing, or CEP, is event processing that combines data from multiple sources to infer events or patterns that suggest more complicated circumstances. The goal of complex event processing is to identify meaningful events (such as opportunities or threats) and respond to them as quickly as possible.

The core benefits of this architecture approach is that it provides loose coupling of the components, IoT transaction database and JBoss Drools/Fusion IoT-AI system. A component publishes events about actions that it is executing and transaction database subscribes/listens to these events. The transaction database subscriber listens for events, stores and inserts the facts into the IoT-AI working memory. An orchestration layer then handles the actual inserting into working memory of only events we are interested in analyzing by the rules inference engine.

These events are notices happening across the various layers of the organization. An event may also be defined as a "change of state," when a measurement exceeds a predefined threshold of time, response, or other value. IoT complex event processing analysts will give the organizations a new way to analyze patterns in real-time and help the business side communicate better with IT and service departments.

After inserted new events into Drools Working Memory from the data collection ingestion the Event Stream Processing, or ESP passes-off to our complex event processing (CEP), which takes precedence.

ESP-Event Stream Processing is a set of technologies which include event visualization, event databases, event-driven middleware and our event processing language (Drools).

CEP - Complex Event Processing

CEP is primarily an event processing concept that deals with the task of processing multiple events with the goal of identifying the meaningful events within the event cloud. CEP employs techniques such as detection of complex patterns of many events, event correlation and abstraction, event hierarchies, and relationships between events such as causality, membership, and timing, and event-driven processes.

CEP deals with the task of processing streams of event data with the goal of identifying the meaningful pattern within those streams, employing techniques such as detection of relationships between multiple events, event correlation, event hierarchies, and other aspects such as causality, consequence and timing. These are inserted in the rules engine and synthetic facts or events that are conclusions of facts. This is the sequencing of synthetic events from actual events/faces and the conclusions drawn.

CEP allows patterns of simple and ordinary events to be considered to infer that a complex event has occurred. Complex event processing evaluates a confluence of events and then takes action. The events (notable or ordinary) may cross event types and occur over a long period of time. The event correlation may be causal, temporal, or spatial. CEP requires the employment of sophisticated event interpreters, event pattern definition and matching, and correlation techniques from the Drools BRMS engine. CEP is commonly used to detect and respond to business anomalies, threats, locations, and opportunities and is well suited for IoT domain.

3.3 Drools Fusion Solution Design

3.3.1 Design Use Case Methodology

Event processing use cases share several requirements and goals with business rules use cases.

These overlaps happen both on the business side and on the technical side.

<u>On the Business side:</u>

- Business rules are frequently defined based on the occurrence of scenarios triggered by events. Examples could be:
  - On an algorithmic trading application: Take an action if the security price increases X% compared to the day opening price where the price increases are usually denoted by events on a stock trade application.
  - On a monitoring application: Take an action if the temperature on the server room increases X degrees in Y minutes where sensor readings are usually denoted by events.
- Both business rules and event processing queries change frequently and require immediate response for the business to adapt itself to new market conditions, new regulations, and new enterprise policies.

<u>From a technical perspective:</u>

- Both require seamless integration with the enterprise infrastructure and applications, especially on autonomous governance, including, but not limited to, lifecycle management, auditing, security, etc.
- Both have functional requirements like pattern matching and non-functional requirements like response time and query/rule explanation.

In this context, Drools Fusion is the module responsible for adding event processing capabilities into the platform.

Supporting complex event processing, though, is much more than simply understanding what an event is. CEP scenarios share several common and distinguishing characteristics:

- Usually required to process huge volumes of events, but only a small percentage of the events are of real interest.
- Events are usually immutable, since they are a record of state change.
- Usually the rules and queries on events must run in reactive modes, i.e., react to the detection of event patterns.
- Usually there are strong temporal relationships between related events.
- Individual events are usually not important. The system is concerned about patterns of related events and their relationships.
- Usually the system is required to perform composition and aggregation of events.

Based on this general common characteristic, Drools Fusion defined a set of goals to be achieved in order to support complex event processing appropriately:

- Support events, with their proper semantics, as first class citizens.
- Allow detection, correlation, aggregation and composition of events.
- Support processing of streams of events.
- Support temporal constraints in order to model the temporal relationships between events.
- Support sliding windows of interesting events.
- Support a session scoped unified clock.
- Support the required volumes of events for CEP use cases.
- Support to (re)active rules.
- Support adapters for event input into the engine (pipeline).

This list of goals are based on the requirements not covered by Drools expert itself since in a unified platform all features of one module are leveraged by the other modules. Drools Fusion is born with enterprise grade features like pattern matching that is paramount to a CEP product but that is already provided by Drools expert. In the same way, all features provided by Drools Fusion are leveraged by Drools flow (and vice-versa) making process management aware of event processing and vice-versa.

Additionally, in some scenarios, you will have to discard equal objects (objects of the same type and values) when they are inserted into the working memory to avoid data inconsistency and unnecessary activations. The preferred method of discarding duplicated facts on insertion is an insertion – use of a custom classLoader in a knowledgeAgenda method.

We can have a system of streams where the events are transmitted and these events can be of the same type but have to be processed in different ways without mixing them in their processing. Drools Fusion can handle this scenario by creating entryPoints that can be used to integrate these streams with the rules patterns to process the events that are going to arrive from these streams.

3.4 Event Semantics

An *event* is a fact that presents a few distinguishing characteristics:

- **Usually immutable:** Since, by the previously discussed definition, events are a record of a state change in the application domain, i.e., a record of something that already happened, and the past cannot be "changed", events are immutable. This constraint is an important requirement for the development of several optimizations and for the specification of the event lifecycle. This does not mean that the Java object representing the object must be immutable. Quite the contrary. The engine does not enforce immutability of the object model because one of the most common use cases for rules is event data enrichment.
  - **Note**: As a best practice, the application is allowed to populate un-populated event attributes (to enrich the event with inferred data), but already populated attributes should never be changed.
- **Strong temporal constraints:** Rules involving events usually require the correlation of multiple events, especially temporal correlations where events are said to happen at some point in time relative to other events.
- **Managed lifecycle:** Due to their immutable nature and the temporal constraints, events usually will only match other events and facts during a limited window of time, making it possible for the engine to manage the lifecycle of the events automatically. In other words, once an event is inserted into the working memory, it is possible for the engine to find out when an event can no longer match other facts and automatically delete it, releasing its associated resources.
- **Use of sliding windows:** Since all events have timestamps associated to them it is possible to define and use sliding windows over them, allowing the creation of rules on aggregations of values over a period of time. Example: Average of an event value over 60 minutes.

Drools supports the declaration and usage of events with both semantics: **point-in-time** events and **interval-based** events.

  - **Note:** A simplistic way to understand the unification of the semantics is to consider a *point-in-time* event as an *interval-based* event whose *duration is zero*.

3.5 Event Processing Modes

Rules engines in general have a well-known way of processing data and rules and provide the application with the results. Also, there are not many requirements on how facts should be presented to the rules engine especially because, in general, the processing itself is time independent. That is a good assumption for most scenarios but not for all of them. When the requirements include the processing of real time or near real time events, time becomes an important variable of the reasoning process.

The following sections will explain the impact of time on rules reasoning and the two modes provided by Drools for the reasoning process.

3.5.1 Cloud Mode

The CLOUD processing mode is the default processing mode. Users of rules engine are familiar with this mode because it behaves in exactly the same way as any pure forward chaining rules engine, including previous versions of Drools.

When running in CLOUD mode the engine sees all facts in the working memory, does not matter if they are regular facts or events as a whole. There is no notion of flow of time, although events have a timestamp as usual. In other words, although the engine knows that a given event was created, for instance, on January 1st 2009, at 09:35:40.767, it is not possible for the engine to determine how "old" the event is because there is no concept of "now".

In this mode, the engine will apply its usual many-to-many pattern matching algorithm using the rules constraints to find the matching tuples, activate, and fire rules as usual.

This mode does not impose any kind of additional requirements on facts. So, for instance:

- There is no notion of time. No requirements clock synchronization.
- There is no requirement on event ordering. The engine looks at the events as an unordered Cloud against which the engine tries to match rules.

On the other hand, since there are no requirements, some benefits are not available either. For instance, in CLOUD mode it is not possible to use sliding windows because sliding windows are based on the concept of "now" and there is no concept of "now" in CLOUD mode.

Since there is no ordering requirement on events it is not possible for the engine to determine when events can no longer match and as so, there is no automatic life-cycle management for events. i.e., the application must explicitly delete events when they are no longer necessary, in the same way the application does with regular facts.

Cloud mode is the default execution mode for Drools but, in any case, as any other configuration in Drools, it is possible to change this behavior either by setting a system property using configuration property files, or using the API. The corresponding property is:

```
KieBaseConfiguration config = KieServices.Factory.get().newKieBaseConfiguration();
config.setOption( EventProcessingOption.CLOUD );
```

The equivalent property is:

```
drools.eventProcessingMode = cloud
```

3.5.2 Stream Mode

The STREAM processing mode is the mode of choice when the application needs to process streams of events. It adds a few common requirements to the regular processing but enables a whole lot of features that make stream event processing a lot simpler.

The main requirements to use STREAM mode are:

- Events in each stream must be time-ordered. i.e., inside a given stream events that happened first must be inserted first into the engine.
- The engine will force synchronization between streams through the use of the session clock, so, although the application does not need to enforce time ordering between streams, the use of non-time-synchronized streams may result in some unexpected results.

Given that the above requirements are met, the application may enable the STREAM mode using the following API:

```
KieBaseConfiguration config = KieServices.Factory.get().newKieBaseConfiguration();
config.setOption( EventProcessingOption.STREAM );
```

Or, the equivalent property:

```
drools.eventProcessingMode = stream
```

When using the STREAM, the engine knows the concept of flow of time and the concept of "now", i.e., the engine understands how old events are based on the current timestamp read from the session clock.

This characteristic allows the engine to provide the following additional features to the application:

- Sliding window support
- Automatic event lifecycle management
- Automatic rule delaying when using negative patterns

With temporal reasoning IoT sensors provide information that Drools AI is acted on immediately.

All these features are explained in the following sections:

3.5.3 Role of Session Clock in Stream mode

When running the engine in CLOUD mode the session clock is used only to timestamp the arriving events that don't have a previously defined timestamp attribute. Although in STREAM mode, the session clock assumes an even more important role.

In STREAM mode, the session clock is responsible for keeping the current timestamp and based on it, the engine does all the temporal calculations on event's aging, synchronizes streams from multiple sources, schedules future tasks and so on.

Check the documentation on the session clock section to know how to configure and use different session clock implementations.

3.5.4 Negative Patterns in Stream Mode

Negative patterns behave different in STREAM mode when compared to CLOUD mode. In CLOUD mode, the engine assumes that all facts and events are known in advance (there is no concept of flow of time) and so, negative patterns are evaluated immediately.

When running in STREAM mode, negative patterns with temporal constraints may require the engine to wait for a time period before activating a rule. The time period is automatically calculated by the engine in a way that the user does not need to use any tricks to achieve the desired result.

For instance:

Example 3.5.4.1. A rule that activates immediately upon matching

```
rule "Sound the alarm"
when
    $f : FireDetected( )
    not( SprinklerActivated( ) )
then
    // sound the alarm
end
```

The above rule has no temporal constraints that would require delaying the rule therefore the rule activates immediately. The following rule on the other hand must wait for 10 seconds before activating since it may take up to 10 seconds for the sprinklers to activate:

Example 3.5.4.2. A rule that automatically delays activation due to temporal constraints

```
rule "Sound the alarm"
when
    $f : FireDetected( )
    not( SprinklerActivated( this after[0s,10s] $f ) )
then
    // sound the alarm
end
```

This behavior allows the engine to keep consistency when dealing with negative patterns and temporal constraints at the same time. The above would be the same as writing the rule as below, but does not burden the user to calculate and explicitly write the appropriate duration parameter:

Example 3.5.4.3. Same rule with explicit duration parameter

```
rule "Sound the alarm"
    duration( 10s )
when
    $f : FireDetected( )
    not( SprinklerActivated( this after[0s,10s] $f ) )
then
```

```
        // sound the alarm
    end
```

The following rule expects every 10 seconds at least one "Heartbeat" event, if not the rule fires. The special case in this rule is that we use the same type of the object in the first pattern and in the negative pattern. The negative pattern has the temporal constraint to wait between 0 to 10 seconds before firing and it excludes the heartbeat bound to $h. Excluding the bound heartbeat is important since the temporal constraint [0s, ...] does not exclude by itself the bound event $h from being matched again, thus preventing the rule to fire.

Example 3.5.4.4. Excluding bound events in negative patterns

```
    rule "Sound the alarm"
    when
        $h: Heartbeat( ) from entry-point "MonitoringStream"
        not( Heartbeat( this != $h, this after[0s,10s] $h ) from entry-point
    "MonitoringStream" )
    then
        // Sound the alarm
    end
```

3.6 Session Clock

Reasoning over time requires a reference clock. Just to mention one example, if a rule reasons over the average price of a given stock over the last 60 minutes, how the engine knows what stock price changes happened over the last 60 minutes in order to calculate the average? The obvious response is by comparing the timestamp of the events with the "current time". How the engine knows what **time is now**? Again, obviously, by querying the session clock.

The session clock implements a strategy pattern allowing different types of clocks to be plugged and used by the engine. This is very important because the engine may be running in an element of different scenarios that may require different clock implementations. Just to mention a few:

- **Rules testing:** Testing always requires a controlled environment and when the tests include rules with temporal constraints it is necessary to not only control the input rules and facts, but also the flow of time.
- **Regular execution:** Usually when running rules in production the application will require a real time clock that allows the rules engine to react immediately to the time progression.
- **Special environments:** Specific environments may have specific requirements on time control. Cluster environments may require clock synchronization through heart beats, or JEE environments may require the use of an AppServer provided clock, etc.
- **Rules replay or simulation:** To replay scenarios or simulate scenarios it is necessary that the application also controls the flow of time.

3.6.1 Available Clock Implementations

Drools provides 2 clock implementations out of the box. The default real time clock, based on the system clock and an optional pseudo clock, controlled by the application.

3.6.2 Real Time Clock

By default, Drools uses a real time clock implementation that internally uses the system clock to determine the current timestamp.

To explicitly configure the engine to use the real time clock, just set the session configuration parameter to real time:

```
KieSessionConfiguration config = KieServices.Factory.get().newKieSessionConfiguration();
config.setOption( ClockTypeOption.get("realtime") );
```

3.6.3 Pseudo Clock

Drools also offers out of the box an implementation of a clock that is controlled by the application that is called Pseudo Clock. This clock is especially useful for unit testing temporal rules since it can be controlled by the application and so the results become deterministic.

To configure the pseudo session clock, do:

```
KieSessionConfiguration config = KieServices.Factory.get().newKieSessionConfiguration();
config.setOption( ClockTypeOption.get("pseudo") );
```

As an example of how to control the pseudo session clock:

```
KieSessionConfiguration config = KieServices.Factory.get().newKieSessionConfiguration();
conf.setOption( ClockTypeOption.get( "pseudo" ) );
KieSession session = kbase.newKieSession( conf, null );

SessionPseudoClock clock = session.getSessionClock();

// then, while inserting facts, advance the clock as necessary:

FactHandle handle1 = session.insert( tick1 );
clock.advanceTime( 10, TimeUnit.SECONDS );
FactHandle handle2 = session.insert( tick2 );
clock.advanceTime( 30, TimeUnit.SECONDS );
FactHandle handle3 = session.insert( tick3 );
```

3.7 Sliding Windows

Sliding windows are a way to scope the events of interest by defining a window that is constantly moving. The two most common types of sliding window implementations are time based windows and length based windows.

The next sections will detail each of them.

- **Important** Sliding Windows are only available when running the engine in STREAM mode. Check the event processing mode section for details on how the STREAM mode works.
- **Important** Sliding windows start to match immediately and defining a sliding window does not imply that the rule has to wait for the sliding window to be "full" in order to match.

  For instance, a rule that calculates the average of an event property on a window:length(10) will start calculating the average immediately, and it will start at 0 (zero) for no-events, and will update the average as events arrive one by one.

3.7.1 Sliding Time Windows

Sliding time windows allow the user to write rules that will only match events occurring in the last X time units.

For instance, if the user wants to consider only the stock ticks that happened in the last 2 minutes, the pattern would look like this:

```
StockTick() over window:time( 2m )
```

Drools uses the "over" keyword to associate windows to patterns.

On a more elaborate example, if the user wants to sound an alarm in case the average temperature over the last 10 minutes read from a sensor is above the threshold value, the rule would look like this:

Example 3.7.1.1. Aggregating values over time windows

```
rule "Sound the alarm in case temperature rises above threshold"
```

```
when
    TemperatureThreshold( $max : max )
    Number( doubleValue > $max ) from accumulate(
        SensorReading( $temp : temperature ) over window:time( 10m ),
        average( $temp ) )
then
    // sound the alarm
end
```

The engine will automatically disregard any SensorReading older than 10 minutes and keep the calculated average consistent.

- **Important** Please note that time based windows are considered when calculating the interval an event remains in the working memory before being expired but an event falling off a sliding window does not mean by itself that the event will be discarded from the working memory, as there might be other rules that depend on that event. The engine will discard events only when no other rules depend on that event and the expiration policy for that event type is fulfilled.

3.7.2 Sliding Length Windows

Sliding length windows work the same way as time windows but consider events based on order of their insertion into the session instead of flow of time.

For instance, if the user wants to consider only the last 10 RHT stock ticks independent of how old they are, the pattern would look like this:

```
StockTick( company == "RHT" ) over window:length( 10 )
```

As you can see, the pattern is similar to the one presented in the previous section but instead of using window:time to define the sliding window, it uses window:length.

Using a similar example to the one in the previous section, if the user wants to sound an alarm in case the average temperature over the last 100 readings from a sensor is above the threshold value, the rule would look like:

Example 3.7.2.1. Aggregating values over length windows

```
rule "Sound the alarm in case temperature rises above threshold"
when
    TemperatureThreshold( $max : max )
    Number( doubleValue > $max ) from accumulate(
        SensorReading( $temp : temperature ) over window:length( 100 ),
        average( $temp ) )
then
    // sound the alarm
end
```

The engine will only consider the last 100 readings to calculate the average temperature.

- **Important** Please note that falling off a length based window is not criteria for event expiration in the session. The engine disregards events that fall off a window when calculating that window, but does not remove the event from the session based on that condition alone as there might be other rules that depend on that event.
- **Important** Please note that length based windows do not define temporal constraints for event expiration from the session, and the engine will not consider them. If events have no other rules defining temporal constraints and no explicit expiration policy, the engine will keep them in the session indefinitely.

3.8 Streams Support

Most CEP use cases have to deal with streams of events. The streams can be provided to the application in various forms, from JMS queues to flat text files, from database tables to raw sockets or even through web service calls. In any case, the streams share a common set of characteristics:

- **Events** in the stream are ordered by a timestamp. The timestamp may have different semantics for different streams but they are always ordered internally.
- **Volumes** of events are usually high.
- **Atomic events** are rarely useful by themselves. Usually meaning is extracted from the correlation between multiple events from the stream and also from other sources.
- **Streams** may be homogeneous, i.e. contain a single type of events, or heterogeneous, i.e. contain multiple types of events.

Drools generalized the concept of a stream as an "entry point" into the engine. An entry point for drools is a gate from which facts come. The facts may be regular facts or special facts like events.

In Drools, facts from one entry point (stream) may join with facts from any other entry point or event with facts from the working memory. Although, they never mix, i.e., they never lose the reference to the entry point through which they entered the engine. This is important because one may have the same type of facts coming into the engine through several entry points, but one fact that is inserted into the engine through entry point A will never match a pattern from an entry point B, for example.

3.8.1 Declaring and Using Entry Points

Entry points are declared implicitly in Drools by directly making use of them in the rule. i.e. referencing an entry point in a rule will make the engine, at compile time, identify and create the proper internal structures to support that entry point for this rule.

So, for instance, let's imagine a banking application where transactions are fed into the system coming from streams. One of the streams contains all the transactions executed in ATM machines. So, if one of the rules says a withdraw is authorized if and only if the account balance is over the requested withdraw amount, the rule would look like:

Example 3.8.1.1. Example of Stream Usage

```
rule "authorize withdraw"
when
    WithdrawRequest( $ai : accountId, $am : amount ) from entry-point "ATM
Stream"
    CheckingAccount( accountId == $ai, balance > $am )
then
    // authorize withdraw
end
```

In the previous example, the engine compiler will identify that the pattern is tied to the entry point "ATM Stream" and will both create all the necessary structures for the rulebase to support the "ATM Stream" and will only match WithdrawRequests coming from the "ATM Stream". In the previous example, the rule is also joining the event from the stream with a fact from the main working memory (CheckingAccount).

Now, let's imagine a second rule that states that a fee of $2 must be applied to any account for which a withdraw request is placed at a bank branch:

Example 3.8.1.2. Using a different Stream

```
rule "apply fee on withdraws on branches"
when
```

```
    WithdrawRequest( $ai : accountId, processed == true ) from entry-point
"Branch Stream"
    CheckingAccount( accountId == $ai )
then
    // apply a $2 fee on the account
end
```

The previous rule will match events of the exact same type as the first rule (WithdrawRequest), but from two different streams. So, an event inserted into "ATM Stream" will never be evaluated against the pattern on the second rule because the rule states that it is only interested in patterns coming from the "Branch Stream".

So, entry points besides being a proper abstraction for streams are also a way to scope facts in the working memory and a valuable tool for reducing cross products explosions. But that is a subject for another time.

Inserting events into an entry point is equally simple. Instead of inserting events directly into the working memory, insert them into the entry point as shown in the example below:

Example 3.8.1.3. Inserting facts into an entry point

```
// create your rulebase and your session as usual
KieSession session = ...
// get a reference to the entry point
EntryPoint atmStream = session.getEntryPoint("ATM Stream" );
// and start inserting your facts into the entry point
atmStream.insert( aWithdrawRequest );
```

The previous example shows how to manually insert facts into a given entry point. Although, usually the application will use one of the many adapters to plug a stream end point like a JMS queue directly into the engine entry point without coding the inserts manually. The Drools pipeline API has several adapters and helpers to do that as well as examples on how to do it.

3.9 Memory Management for Events

- **Important** The automatic memory management for events is only performed when running the engine in STREAM mode. Check the event processing mode section for details on how the STREAM mode works.

One of the benefits of running the engine in STREAM mode is that the engine can detect when an event can no longer match any rule due to its temporal constraints. When that happens, the engine can safely delete the event from the session without side effects and release any resources used by that event.

There are basically 2 ways for the engine to calculate the matching window for a given event:

- Explicitly, using the expiration policy
- Implicitly, analyzing the temporal constraints on events

3.9.1 Explicit expiration offset

The first way of allowing the engine to calculate the window of interest for a given event type is by explicitly setting it. To do that, just use the declare statement and define an expiration for the fact type:

Example 3.9.1. Explicitly defining an expiration offset of 30 minutes for StockTick events

```
declare StockTick
    @expires( 30m )
end
```

The above example declares an expiration offset of 30 minutes for StockTick events. After that time, assuming no rule still needs the event, the engine will expire and remove the event from the session automatically.

- **Important** An explicit expiration policy for a given event type overrides any inferred expiration offset for that same type.

3.9.2 Inferred expiration offset

Another way for the engine to calculate the expiration offset for a given event is implicitly, by analyzing the temporal constraints in the rules. For instance, given the following rule:

Example 3.9.2.1. Example rule with temporal constraints

```
rule "correlate orders"
when
    $bo : BuyOrderEvent( $id : id )
    $ae : AckEvent( id == $id, this after[0,10s] $bo )
then
    // do something
end
```

Analyzing the above rule the engine automatically calculates that whenever a BuyOrderEvent matches, it needs to store it for up to 10 seconds to wait for matching AckEvent's. So, the implicit expiration offset for BuyOrderEvent will be 10 seconds. AckEvent, on the other hand can only match existing BuyOrderEvent's and so its expiration offset will be zero seconds.

The engine will make this analysis for the whole rulebase and find the offset for every event type.

- **Important** An explicit expiration policy for a given event type overrides any inferred expiration offset for that same type.

3.10 Temporal Reasoning

Temporal reasoning is another requirement of any CEP system. As discussed previously, one of the distinguishing characteristics of events is their strong temporal relationships in **IoT**.

With temporal reasoning IoT sensors provide information that AI is acted on immediately. In Drools AI-IoT, judging the impact avoidances of a vehicle and making course adjustments is an example of Drools AI temporal reasoning. The distention is acting on events and not reasoning over data, as in Cloud.

Temporal reasoning is a type of stream reasoning and is an extensive field of research from its roots on temporal modal logic to its more practical applications in business systems. There are hundreds of papers and thesis written and approaches are described for several applications. Drools takes a pragmatic and simple approach based on several sources about maintaining knowledge about temporal intervals which make it an elegant solution for **IoT**.

Drools implements the interval-based time event semantics described by Allen, and represents point-in-time events as interval-based events with duration 0 (zero). Events or alerts are raised by the Arduino Tron IoT devices and indicate a change in condition, again elegant for a Drools rules AI-IoT solution.

3.10.1 Temporal Situational Awareness (SA)

As distributed IoT sensors and applications become larger and more complex, the simple processing of raw sensor and actuation data streams becomes impractical. Instead, data streams must be fused into tangible facts, information that is combined with knowledge to perform meaningful operations.

In current IoT systems, sensing and actuation is mostly done at the bare bones data level, whereas many IoT applications demand higher level situation awareness of - and reasoning about - the systems' states and the physical environment where they operate to preform intelligent decisions.

Situational Awareness (SA) is the perception of environmental elements by our IoT devices and events with respect to time or space, the comprehension of their meaning, and the projection of their status after some variable has changed, such as time, or some other variable, such as a predetermined event. This is our Drools-IoT judging and making decisions after cognitive situational reasoning.

3.10.2 Complex Event Processing

Event Stream Processing, or ESP, is a set of technologies which include event visualization, event databases, event-driven middleware and our event processing language (Drools). After inserting events, the ESP passes-off to our complex event processing (CEP), which takes precedence.

The manipulations of events are described by CEP rules, which are event-condition-actions that combine continuous query primitives with context operators (e.g. temporal, logical, quantifiers) on received events, checking for correlations among these events, and generating complex (or composite) events that summarize the correlation of the input events. Most CEP systems have the concept of Event Processing Agents (EPAs), which are modules that implements event processing workflows.

3.10.3 IoT - Internet of Things Reasoning

The IO paradigm aims at connecting billions of IoT devices to the internet. This requires suitable architecture and technologies capable of bridging the vast heterogeneity of the devices to provide meaningful services. To enable this seamless integration of devices to provide sophisticated services, the concept of AI reasoning has to address a number of issues with the growing number of devices e.g. scalability, heterogeneity, and reliability.

3.10.4 Temporal Operators

Drools implements all 13 operators defined by Allen and also their logical complement (negation). This section details some of the operators and their parameters used in IoT.

3.10.5 After

The after evaluator correlates two events and matches when the temporal distance from the current event to the event being correlated belongs to the distance range declared for the operator.

Let's look at an example:

```
$eventA : EventA( this after[ 3m30s, 4m ] $eventB )
```

The previous pattern will match if and only if the temporal distance between the time when $eventB finished and the time when $eventA started is between (3 minutes and 30 seconds) and (4 minutes).

3.10.6 Before

The before evaluator correlates two events and matches when the temporal distance from the event being correlated to the current correlated belongs to the distance range declared for the operator.

Let's look at an example:

```
$eventA : EventA( this before[ 3m30s, 4m ] $eventB )
```

The previous pattern will match if and only if the temporal distance between the time when $eventA finished and the time when $eventB started is between (3 minutes and 30 seconds) and (4 minutes).

3.10.7 Coincides

The coincides evaluator correlates two events and matches when both happen at the same time. Optionally, the evaluator accept thresholds for the distance between events start and finish timestamps.

Let's look at an example:

```
$eventA : EventA( this coincides $eventB )
```

The previous pattern will match if and only if the start timestamps of both $eventA and $eventB are the same AND the end timestamp of both $eventA and $eventB also are the same.

Optionally, this operator accepts one or two parameters. These parameters are the thresholds for the distance between matching timestamps.

- If only one parameter is given, it is used for both start and end timestamps.
- If two parameters are given, then the first is used as a threshold for the start timestamp and the second one is used as a threshold for the end timestamp.

3.10.8 During

The during evaluator correlates two events and matches when the current event happens during the occurrence of the event being correlated.

Let's look at an example:

```
$eventA : EventA( this during $eventB )
```

The previous pattern will match if and only if the $eventA starts after $eventB starts and finishes before $eventB finishes.

3.10.9 Finishes

The finishes evaluator correlates two events and matches when the current events start timestamp happens after the correlated events start timestamp, but both end timestamps occur at the same time.

Let's look at an example:

```
$eventA : EventA( this finishes $eventB )
```

The previous pattern will match if and only if the $eventA starts after $eventB starts and finishes at the same time $eventB finishes.

3.10.10 Includes

The includes evaluator correlates two events and matches when the event being correlated happens during the current event. It is the symmetrical opposite of during evaluator.

Let's look at an example:

```
$eventA : EventA( this includes $eventB )
```

The previous pattern will match if and only if the $eventB starts after $eventA starts and finishes before $eventA finishes.

3.10.11 Starts

The starts evaluator correlates two events and matches when the current event end timestamp happens before the correlated event's end timestamp, but both start timestamps occur at the same time.

Let's look at an example:

```
$eventA : EventA( this starts $eventB )
```

The previous pattern will match if and only if the $eventA finishes before $eventB finishes and starts at the same time $eventB starts.

3.10.12 Started By

The started by evaluator correlates two events and matches when the correlating events end timestamp happens before the current events end timestamp, but both start timestamps occur at the same time. Let's look at an example:

```
$eventA : EventA( this startedby $eventB )
```

The previous pattern will match if and only if the $eventB finishes before $eventA finishes and starts at the same time $eventB starts.

4 Rules Writing Performance Memory and Testing

4.1 Drools Writing Rules Best Practice

Drools Rules Practices

Drools performance is based on how Rete trees and nodes are created, how Drools indexes them, and why increasing number of objects in Drools hardly effects the total time taken to execute it. Ruleswritten in an intelligent way can drastically reduce the number of nodes in the Rete tree, thus, further increasing memory and impacting the performance.

Some Drools rules writing best practice, and executing the rules as fast as possible:

- Put the most restricting condition on the top
- The conditions that you feel should be on the highest priority - put them on the top
- The then conditions that you use should be diligently prepared
- Use the same order of conditions across your rules
- Do not use eval unless you have to
- Put evals at the bottom of your conditions
- Do not use if statements inside consequences
- Using shortcuts for Booleans cause JIT errors on Drools 5.4 so do use them as
  House (windowOpen == true) not House (windowOpen)
- Do not use salience. In most cases it leads to maintenance issues
- Plan using an Eclipse-Drool UI to create good rules
- Never attempt using if-statements inside the then part
- Use shortcuts for Boolean because they often cause errors
- Always follow the pattern of RWTE - i.e, 1. RULE 2. WHEN 3. THEN 4. END
- Avoid using salience. It causes troubles in most cases
- Try to integrate the rules with custom classes
  rather than predefined sets to be used for your operations
- The condition that you are using when part should be interlinked and not null
  (i.e, the condition should be linked to some values which have existence)
- Always use the Drools generalized concept of a stream as an "entry point" into the engine
  An entry point is for drools a gate from which facts come, the source where there were inserted
  The facts may be regular facts or special facts like events
- Use the import statements properly. Import statements work like import statements in Java. You need to specify the fully qualified paths and type names for any objects you want to use in the rules. Drools automatically imports classes from the Java package of the same name, and also from the package java.lang

- **Package**: Every rule starts with a package name. The package acts as a namespace for rules. Rule names within a package must be unique. Packages in rules are similar to packages in Java. They serve the same purpose.

- **Import statement**: Whatever facts you want to apply the rule on, those facts needs to be imported into your application.

- **Rule definition**: Consists of the rule name, the condition, and the consequence. Drools keywords are **rule, when, then,** and **end**. The **when** part is the condition in both the rules and the **then** part is the consequence.

- **Load the rules once, batch insert all facts and fire once:** Letting the engine work out the most optimal way to execute is more efficient and easier to maintain from the development perspective. It also prevents the rules being loaded/parsed multiple times before getting the desired outcome.

- **Don't overload rules:** Each rule should describe one and only one scenario. The engine will optimize shared conditions: i.e. rules that share conditions of a fact (in the same order) share their Rete nodes.

4.2 Drools Performance and Memory Internals

Drools Rules "lots of objects" and "complex logic in sequence"

JBoss Drools - The keywords for performance impact are "lots of objects" and "complex logic in sequence". JBoss Drools uses Rete's algorithm to execute rules. Rete's algorithm is an efficient pattern matching algorithm. In the later versions of Drools, the Phreak engine optimization has been added and this has greatly improved performance, making the engine lazy evaluation instead of eggier evaluation.

JBoss Drools has its own implementation of Rete's algorithm. A rule in Drools is represented by a Rete tree. A Rete tree consists of nodes. These nodes are mostly conditional evaluations. Everything in a Drools rule is represented by a Rete tree node. Apart from conditional nodes, the Rete tree also consists of AND nodes, OR nodes, and start/end nodes (and a few other types of nodes as well).

The main part of the algorithm is the creation of the Rete tree. Whenever a fact (object) is inserted in the Drools engine, a Rete tree is created. The creation of this Rete tree is done by some intelligent algorithm. The Rete tree, once created, executes in almost no time over the facts (objects) and gives the result. Most of the time is spent creating the Rete tree rather than executing it.

This is something that you can also experience during debugging. Whenever a fact is inserted into the Drools session it takes a bit of time. However, the firing of rules is almost instantaneous.

So, the way this Rete algorithm has been implemented inside Drools accounts for its efficiency.
But, what will happen to the JBoss Drools efficient Rete algorithm when "LOTS OF OBJECTS" will come into picture?

The answer lies in two techniques that Drools uses to store nodes: Node Sharing and Node Indexing.

Drools caches nodes while building Rete’s tree which is known as node sharing. Whenever a new node is created, it’s checked whether there is an equivalent node already present in the cache. If an equivalent node is found in the cache, the cached node is used instead and the new node is discarded. This makes Drools more memory efficient.

Drools keeps a hash table of the object properties and Rete tree nodes. It is known as node indexing and is used to avoid evaluating the same conditions multiple times. Node indexing speeds up the propagation of nodes in the Rete network which accounts for high performance of the Drools engine.

The in depth analysis of Rete tree creation and node propagation in the Rete network tells that the way rules are written might also effect the performance as it directly impacts the propagation in Rete tree. Rules written in an intelligent way can drastically reduce the number of nodes in the Rete tree, thus, further increasing the performance.

So, these techniques helps Drools to process large number of objects efficiently. Conclusion is - increasing number of objects in Drools hardly effects the total time taken to execute it.

4.3 Drools Testing Rules Methodology

Drools Rules tested as code or data?

Should business rules be embedded as a part of the application code that doesn't change very often or are rules more like your application data (for example, pricing lists), which you expect to change on almost a daily basis?

This comes up often. Depending on our answer, we will deploy our rules very differently.

The answer, somewhat confusing, is that rules are both.

- Rules are as powerful as the normal code and should be treated in the same way. (For example, before deployment, any changes should be thoroughly tested.)
- Rules are as easy to change as data because first, they live outside the “normal” application and second, rule engines are expressly designed to easily allow changes to the business rules.

So, we are really saying “**both**”, depending on impact.

4.3.1 Testing of the Rules

Testing of the rules is achieved by means of unit testing each rule or a couple of rules representing a certain scenario. Each such test case is covered by several unit tests attempting to evaluate a different situation. The tests comprising these unit tests are grouped in compliance with the separation of the rules into .drl files. In other words, a test may add into knowledge builder only the .drl file holding the declarations and the .drl file representing the tested logic.

Each test is composed of unit tests and a before and after method. The before method is responsible for composing the session before each unit test and the after method for correct disposal of it. The constructing of the session is performed in the similar way as in the init phase of the application with the exception of resources, channels, and clock.

Only the resources necessary for the scenario are used for creating knowledge packages. The mock objects are substituted for actual channels as they require the application server to operate.

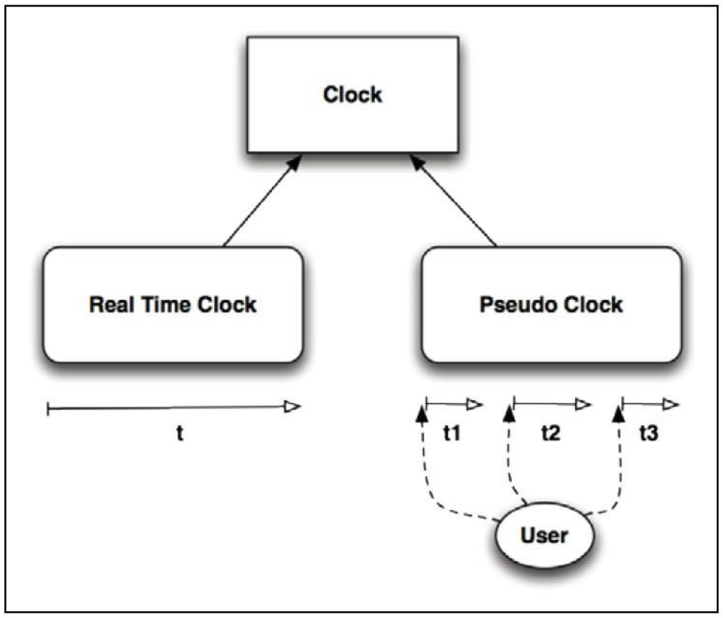


Figure 4.3.1.1: The two Drools clock implementations.

Due to the fact that many of the rules employ the temporal reasoning aspects, the clock implementation in the tests must be different. Drools provides two clock implementations demonstrated in Figure 13.1, where the Real Time Clock applies the JVM clock and Pseudo Clock enables the application to control the flow of time in all different ways. In order for the real-time clock to be the default option, the setting of the pseudo-clock has to be configured during creating the session.

4.3.2 Unit Testing Rules

An important point to note is that you should carry out unit testing in the rules that you write. It is manual unit testing, but we still checked that your blocks of rules produced the outcome that you expected. All we're talking about here is automating the process.

Unit testing also has the advantage of documenting the code because it gives a working example of how to call the rules. It also makes your rules and code more reusable. You've just proved (in your unit test) that you can call your code on a standalone basis, which is an important first step for somebody else to be able to use it again in the future.

Run tests with a small amount of data on all of your rules, i.e. with a minimal number of facts in the rule session and test the results that particular rule was fired. For the sample data, use static data and define minimal test data for each rule test. You are texting that each particular rule fires.

5 Arduino Tron AI-IoT Drools-jBPM Business Process Management

5.1 AI-IoT Artificial Intelligent Reasoning

5.1.1 IoT AI-Artificial Intelligent Smart Things Automation

The Internet of Things (IoT) refers to a network of connected devices collecting and exchanging data and processes over the internet. IoT promises to provide "smart" environments (homes, cities, hospitals, schools, stores, offices, etc.) and smart products (cars, trucks, airplanes, trains, buildings, devices, etc.). While this data is useful, there is still "a-disconnect" in integrating these IoT devices with mission-critical business processes and corporate cloud data awareness.

The task of moving IoT devices beyond "connected" to "smart" is daunting. Moving beyond collecting IoT data and transitioning, to leveraging this new wealth of IoT data, to improving the smart decision making process is the key to automation. Artificial Intelligence (**AI** will help these IoT devices, environments and products to self-monitor, self-diagnose and eventually, self-direct. This is what we said in the opening of this book, "If a machine thinks, then a machine can do."

But one of the key concepts in enabling this transition from connected to smart is the ability to perform **AI Analytics**. The traditional analytic models of pulling all data in to a centralized source such as a data warehouse or analytic sandbox is going to be less useful. We are not trying to just analyze complex IoT data,we are trying to make smart decisions and take actions base on our AI Analytics of IoT devices.

***IoT Definition** – IoT is the integration of computer-based systems into our physical-world.*

Our world is increasingly linked through the number of already connected IoT devices. IoT components equipped with sensors and actuators that enabling sensing, acting, collecting and exchange data via various communication networks including the internet. These IoT devices such as wearable, GPS, smartphones, connected cars, vending machine, smart homes, and automated offices, are used in areas such as supply chain management, intelligent transport systems, robotics, remote healthcare, business processes can rapidly gain a competitive edge by using the information and functionalities of IoT devices (sensors and actuators). Business processes use IoT information to incorporate real world data, to take informed decisions, optimize their execution, and adapt itself to context changes.

In addition, the increase in processing power of IoT devices enables them to take part in the execution of the business logic. This way IoT devices can aggregate and filter data, and make decisions locally by executing parts of the business logic whenever central control is not required, reducing both the amount of exchanged data and of central processing.

The power of the IoT device increases greatly when business process (jBPM) can use them to provide information about our real-world as well as execute IoT device actions as part of our business process. The jBPM-BPMN modular allow us to define both the business processes and IoT devices behavior at the same time using one diagram. In our examples we will be adding Drools-jBPM to IoT devices. Making **"Things Smart"** is the application of AI to IoT platform via DroolsRules Inference Reasoning, jBPM and ES-Expert Systems Architecture.

With the use of AI Drools-jBPM analysis and reasoning in IoT devices, we were able to orchestrate dissimilar devices that normally have no awareness of each other. This creates opportunities for direct integration of computer-based into the physical world that has never been available before. This results in improved efficiency, accuracy, and economic benefits by increased automation and reduced intervention. This IoT orchestration of IoT devices give us the ability for action after our AI decision.

5.1.2 IoT Human Interface or Human-Task Node

Another important aspect of IoT AI Drools-jBPM business processes management is the human interface and system interaction. While some of the work performed in an IoT jBPM process can be executed automatically, some tasks may need to be executed by human actors. jBPM supports a special human task node inside processes for modeling this interaction with human users. This human task node allows process designers to define the properties related to the task that the human actor needs to execute.

Consider that our IoT device may raise an alarm, or alert to a device or process fault condition or action. The jBPM supports the use of human tasks inside processes using a user task node. A user task node represents an atomic task that needs to be executed by a human actor (in this example maybe answer the alarm). As far as the jBPM engine is concerned, human tasks are similar to any other external service that needs to be invoked and are implemented as a domain-specific service.

Because a human task is an example of such a domain-specific service, the process itself contains a high-level, abstract description of the human task that need to be executed, and a work item handler is responsible for binding this abstract tasks to a specific implementation of the human task.

The IoT AI Drools-jBPM project provides a default implementation of a human task service based on the WS-Human-Task specification. If you do not have the requirement to integrate an existing human task service you can use this service. It manages the life cycle of the tasks (creation, claiming, completion, etc.) and stores the state of the tasks. To have human actors participate in your IoT processes:

1. Include human task nodes inside your process to model the interaction with human actors
2. Integrate a task management component (e.g. the WS-Human-Task provided by jBPM)
3. Have the end-users interact with a human task IoT client interface.

How IoT can benefit from jBPM? Let us consider a complex system with multiple components interacting within a smart environment being aware of the components' locations, movements, and interactions. Such a system can be a smart factory with autonomous robots, a retirement home with connected residents, or, at a larger scale, a smart city. While the parties in the system can track the movements of each component and also relate multiple components' behaviors to each other, they do not know the components' agendas. Often their interactions are based on habits, i.e., routine low-level processes, which represent recurring tasks. Some of these routines are more time and cost critical than others, some may be dangerous or endanger others, and some may just be inefficient or superfluous. Knowing their agendas, their goals, and their procedures can enable a better basis for planning, execution, and safety.

How jBPM can benefit from IoT? Let us consider a complex process with multiple parties interacting in the context of a business transaction. Such a process can be, for example, a procurement process, where goods are ordered, delivered, stored, and paid for. While the system can track each automatically executed activity on its own, it relies on messages from other parties and manually entered data in the case of manual activities. If this data is not entered or entered incorrectly, discrepancies between the digital (i.e., computerized representation) process and the real-world execution of the process occur. Similar concerns hold if the process participants do not obey the digital process under certain circumstances (e.g., an emergency in healthcare) or have not entered the data yet though in the real-world process the respective activity was already executed.

Such scenarios might be better manageable when closely linking the digital process with the physical world as enabled by the integration of IoT and jBPM; e.g., the completion of manual activities can be made observable through usage of appropriate sensors. IoT can complete jBPM with continuous data sensing and physical actuation for improved decision making. Decisions in processes require relevant information as basis for making meaningful decisions. Data from the IoT, such as events, provided through in-memory databases or **CEP** (Complex Event Processing) can be useful in this context.

5.1.3 AI-IoT Drools-jBPM Artificial Intelligent Reasoning Makes IoT Smart

Drools AI is used to mix Business Processes (jBPM) with Business Rules (Reasoning), to define advanced and complex scenarios. Also, Drools rule engine adds the ability of temporal reasoning, allowing business processes to be monitored, improved, and cover business scenarios that require temporal inferences. Event stream processing focused on the capabilities of processing streams of events in (near) real time, while the main focus of CEP (Complex Event Processing) was on the correlation and composition of atomic events into complex (compound) events. IoT for CEP is primarily an event processing concept that deals with the task of processing multiple events with the goal of identifying the meaningful events within the IoT event cloud. CEP in IoT employs techniques for detection of complex patterns of many events, event correlation and abstraction, and event hierarchies.

5.2 IoT Arduino Tron Architecture

The power of the IoT device increases greatly when business process (jBPM) can use them to provide information about our real-world as well as execute IoT (devices) as part of our business process. Arduino Tron adds Drools-jBPM to these IoT "smart" devices. At the beginning of chapter two we introduced the EOSpy/Arduino Tron technology stack diagram and now we will review each component. Executive Order EOSpy provides us the three tiered architecture to provide a complete AI-IoT system.

- **AI (Drools-JBPM):** AI-IoT the Internet of Things Drools-jBPM Expert System.
- **Server (EOSpy):** Sensor Processor live map GPS Tracking, Analysis of IoT Data
- **IoT (Arduino Tron):** Android Environment Sensors, IoT Data Collection and GPS

5.2.1 AI (Drools-jBPM) - IoT Internet of Things Expert System

The Executive Order Corp Arduino Tron - Arduino ESP8266 MQTT Telemetry Transport Machine-to-Machine (M2M) / Internet of Things (IoT) software and Arduino Tron MQTT AI-IoT Client using Arduino Tron AI-IoT Drools-jBPM latest software can be download from the Github website.

Download Arduino Tron from: https://github.com/eodas/EOSpy

GIT the EOSPY AI-IoT from the source code repository, and Import Existing Maven project.

Drools – Allows fast and reliable evaluation of business rules and complex event processing.
- A rule engine is a fundamental building block to create an expert system; an AI/ES System
- Drools can reason to a conclusion (infer) beyond what we currently know
- An inference model provides a conclusion reached on the basis of evidence and reasoning
- We say that; Drools emulates the decision-making ability of a human expert

Drools Engine Type Definitions

Forward Chaining

- Forward Chaining is "data-driven" Drools method of deriving a particular goal from a given knowledge base and set of inference rules.

The application of inference rules results in new knowledge (from the consequents of the relations matched), which is then added to the knowledge base. In forward chaining, the system starts from a set of facts, and a set of rules, and tries to find a way of using those rules and facts to deduce a conclusion or come up with a suitable course of action.

Usually, when a rule is triggered, it is then fired, which means its conclusion is added to the rules facts database. If the conclusion of the rule that has fired is an action or a recommendation, then the system may cause that action to take place or the recommendation to be made.

Backwards Chaining

- Backward chaining is a goal driven method of deriving a particular goal from a given knowledge base and set of inference rules. Inference rules are applied by matching the goal of the search to the consequents of the relations stored in the knowledge base.

In backward chaining, we start from a conclusion, which is the hypothesis we wish to prove, and we aim to show how that conclusion can be reached from the rules and facts in the database. The conclusion we are aiming to prove is called a goal, and so reasoning in this way is known as goal-driven reasoning.

Backward chaining starts with the goal state, which is the set of conditions the agent wishes to achieve in carrying out its plan. It now examines this state and sees what actions could lead to it. Prolog is backwards chaining AI-ES.

jBPM Business Process Management

jBPM is a flexible Business Process Management (BPMN 2.0) that allows you to model, execute, and monitor business processes throughout their life cycle. Business Process Management (jBPM) was established to analyze, discover, design, implement, execute, monitor and evolve collaborative business processes within and across organizations.

A business process allows you to model business goals by describing the steps that need to be executed to achieve those goals, and the order of those goals are depicted using a flow chart. Executable business processes bridge the gap between business, users, developers and IoT devices as they are higher-level and use domain-specific concepts that are understood by business users but can also be executed directly by developers and IoT devices.

Additionally, jBPM is an extremely time-sensitive and responsive technology that allows time-critical, dynamic business processes to be changed quickly and while processes are still in progress. This means that jBPM systems can take advantage of the real-time nature of data coming from and going to our IoT devices. This is an ideal fit for out IoT business needs. jBPM supports human-centric, system-centric and hybrid scenarios. In a human-centric scenario, the jBPM system factors in the human element in the business process, putting the person in the center of decision-making and action. This makes it a great match for IoT medical and wearable technology advances.

Where is the human role in this increasingly systemized world? The beauty of IoT and jBPM is that the technology becomes an important factor for its users. Systems can guide and advise and leave the most difficult decisions to the experts. Hand in hand, users and their system will be better equipped to provide easier, faster and more optimized service. The integration between IoT devices and jBPM presents a viable solution with a bright future – one that will connect people, things and systems together as part of business-critical processes.

OptaPlanner – A Constraint resource solver that optimizes use cases such as message routing, employee roistering, vehicle routing, task assignment and cloud optimization. OptaPlanner is not used directly in the EOSpy AI-IoT Drools-jBPM system. The OptaPlanner is covered extensively in the next chapter, EOSpy AI-IoT OptaPlanner Constraint Solver Reasoning

5.2.2 Server (EOSpy) - Sensor Processor Map GPS Tracking and Analysis of IoT Data

EOSpy Server Web application (Webapp) is a server application that delivers EOSPY – Executive Order Sensor Processor sYstem GPS information over the internet through a web browser interface. The EOSPY server main control window ties all location and environment monitoring information on one GPS web browser map screen.

The EOSPY server is designed to support as many tracking devices as possible from popular GPS vendors. EOSPY server also works with many different browsers, including you mobile phone and tablet device browser. EOSPY – Executive Order Sensor Processor sYstem Server mobile application for viewing “Real Time” live GPS tracking information over the internet/mobile cell network.

To install the EOSPY server program on your windows computer, download the eospy.exe installation program and click on the eospy.exe install program. EOSPY will by default install in the destination location: *C:|Program Files|EOSpy Server* and create a Start Menu folder: EOSPY on your desktop.

To start the EOSPY server, click on the Eagle icon on your desktop. The EOSPY login and map will appear in your browser. The default email and password are both: admin

You can have an unlimited number and combination of EOSPY clients and/or GPS tracking devices in use with EOSPY Server.

Configure Arduino Tron, EOSpy Client (Android), or GPS Tracking Devices – Many companies make various off-the-shelf GPS tracking devices. Configuring these devices will vary a little from vendors. First, add the new device with a unique identifier into the EOSPY – Executive Order Sensor Processor sYstem Server. Next, configure your device to use the appropriate EOSPY Server IP address and port number. If the device fails to report, check the IP Address and Device ID.

5.2.3 IoT (Arduino Tron) - Android Environment Sensors, IoT Data Collection and GPS

The EOSPY Client is all of the IoT devices you have in the physical-world that transmit data to the EOSpy Server. These are the Arduino Tron (Sensor and Server versions from Github), Android Client application from the Google Store (standard or TI-SensorTag versions), the GSM/GPRS/GPS tracking devices you can purchase from popular GPS vendors and any other device you buy or build.

EOSpy (Android) Standard and TI-SensorTag Client

The EOSPY-TI SensorTag Client is the GPS tracking automation and the TI BLE SensorTag remote monitoring system is a complete package for business office or personal use. To install the EOSPY Client (Android) application on your phone, download the EOSPY application from the Google App Store. To start the EOSPY Client, click on the Eagle icon on your phone. The EOSPY Client screen will appear. You can also download the EOSPY TI-SensorTag Client version.

The EOSPY-TI SensorTag Client Android app also sends remote temperature sensor, humidity sensor, ambient light level, SensorTag buttons, and magnetometer information to the EOSPY live map server. EOSPY-TI SensorTag wireless GPS tracking allows you to monitor office systems, personal property and fleet from anywhere in the world. Receive remote information from any number of events like when an employee arrives on-site to where a vehicle is located. The EOSPY-TI SensorTag reader will read all sensors from the TI-SensorTag Bluetooth LE device. EOSPY-TI will send GPS position and remote sensor TI-SenorTag data for ambient temperature, IR object temperature, humidity sensor, pressure sensor, ambient light, accelerometer, gyroscope, magnetometer, digital microphone, magnetic sensor, and simple button press, magnetometer and additional information.

To configure a new EOSPY Client you will need to enter the EOSPY server address, domain name, or IP address into the server address. Next add this device in the EOSPY server by entering the device name and the device identifier. Swipe the service status On and YOU'RE DONE. The device will appear on the EOSPY server map the next time the EOSPY Client sends GPS position information.

GSM/GPRS/GPS Tracking Devices

EOSPY supports more than 90 GPS communication protocols and more than 800 models of GPS tracking devices from popular GPS vendors. Many companies make various off-the-shelf GPS tracking devices. Review the list of supported devices for information about your GPS tracking Device. Configuring these devices will vary a little from vendors. First, add the new device with a unique identifier into the EOSPY Executive Order Sensor Processor sYstem Server. Next, configure your device to use the appropriate EOSPY server IP address and port number.

EOSpy Arduino Tron (Sensor and Server) Application

The EOSPY AI-IoT Arduino Tron ESP8266 MQTT telemetry transport Machine-to-Machine (M2M)/IoT system is built on two Arduino Tron software components.

- The EOSPY AI-IoT Arduino Tron Sensor software allows you to send MQTT Telemetry Transport information from external WiFi connected Arduino devices to the EOSPY AI-IoT Server.
- The EOSPY AI-IoT Arduino Tron Server software interface allows you to send commands with the EOSPY AI-IoT Server to control external Arduino connected devices.

To install the EOSPY Arduino Tron application on your Arduino Device, download the EOSPY Arduino Tron Sensor/Server application from GIT.

The Arduino Tron WiFi MQTT was designed as an extremely lightweight publish/publish messaging transport. It is useful for connections with remote locations where a small code footprint is required and/or network bandwidth is at a premium. For example, it has been used in sensors communicating to a broker via satellite link, and in a range of home automation and small device scenarios.

In a decentralized approach, Arduino Tron IoT devices (sensors and actuators) can work together to execute parts of business processes, reducing the number of exchanged messages and promoting central process engine scalability, since information is processed locally and then forwarded.

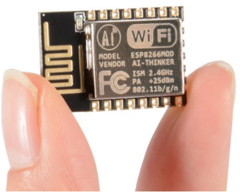
The Arduino Tron Server, IoT processes are provided as web services and, in this way, can also be integrated with business processes. The Arduino Tron Sensor, IoT processes and sends information automatically to the EOSpy Server at intervals during the IoT devices loop sequence of operation. Also, the Arduino Tron Sensor can also send information in response to an event or action.

The Arduino Tron (Sensor and Server) software is covered extensively in the next section, EOSpy Arduino Tron ESP8266 MQTT telemetry transport software.

5.3 Arduino Tron ESP8266 MQTT Telemetry Transport

- **Arduino Tron – Smart Micro-Miniature IoT WiFi MQTT Devices**

Arduino Tron – A Miniature Smart Arduino ESP8266 MQTT Telemetry Transport WiFi NodeMCU Device.



The Arduino Tron smart micro device is about the size of your thumb and can fit into the smallest spaces in your equipment cabinets. The Arduino Tron micro device can send alerts on equipment failures, faults or service conditions. This keeps you in constant contact with your equipment, employees, assets, field equipment, and provides you instant alerts to conditions.

The EOSpy (Executive Order Sensor Processor System) Arduino Tron is an excellent, proven, pre-build, platform application that allows you to use a mobile Arduino MQTT telemetry transport device. It can report location and additional information to EOSpy at selected time intervals. The EOSpy / Arduino Tron application provides a solid platform that your company can build its own custom dedicated application on using an internet-connected or mobile cell phone network connected Arduino device for GPS location, environment, and condition or reporting device (board) error and status information remotely.

In addition to the Arduino NodeMCU sensors such as light sensor, pressure sensor, temperature and humidity sensor, the Arduino NodeMCU can receive action commands from EOSpy/HTTP for 7 seg display, relay, buzzer, infrared emitter, LED, motor actuators, gate access, auditable speech, alarms.

Executive Order provides custom software and hardware development for Arduino MQTT, NodeMCU, (ESP8266 WiFi microcontroller), low cost, smart IoT, WI-FI Enabled, Lua 5.1.4 devices, we provide design, assemble, produce, and test electronic components and printed circuit board (PCB) assemblies for Original Equipment Manufacturers (OEMs). With the EOSpy AI-IoT Arduino Tron system, we have touched only a small fraction of the design possibilities for IoT devices.

5.3.1 AI-IoT Arduino Tron Sensor

The EOSPY / AI-IoT Arduino Tron sensor software allows you to interface and send MQTT telemetry transport information from your external connected Arduino devices to the EOSpy server. The AI-IoT Arduino Tron server software uses a WiFi wireless transceiver interface to stream telemetry information to the EOSpy server for any control module sensors or remote control connected Arduino device.

The Executive Order Corp Arduino Tron - Arduino ESP8266 MQTT telemetry transport Machine-to-Machine (M2M) /IoT software and Arduino Tron MQTT AI-IoT Client using EOSpy. To install the EOSPY Arduino Tron application on your Arduino Device, download the EOSPY Arduino Tron Sensor application from the Github website.

Download Arduino Tron from: https://github.com/eodas/EOSpy

GIT the EOSPY AI-IoT from the source code repository, and Import Existing Maven project.

Update the with WiFi network values for network SSID (name) and network password.

```
// Update these with WiFi network values
const char* ssid     = "your-ssid"; // your network SSID (name)
const char* password = "your-password"; // your network password
```

Update the EOSPY Server IP address and unique unit ID values and add in EOSPY Server.

```
// Update these with EOSpy service IP address and unique unit id values
byte server[] = { 10, 0, 0, 2 }; // Set EOSpy server IP address as bytes
String id = "334455"; // Device unique unit id
```

You will need to set a different device unique identifier for each one of your Arduino Tron Sensor ESP8266 MQTT devices. Then match the Arduino Tron sensor device unique identifier to the device unique unit ID in the EOSpy server application. If your Arduino Tron sensor device is reporting or you don't know your device identifier you can configure your device first and look at the server log file.

Above are all the fields you need to provide values, the remaining fields are used in the Arduino Tron sensor application. Also, you may use a DHT11 digital temperature and humidity sensor. See the Arduino Tron sensor sketch for more details and information.

```
const bool readPushButton = true;
                    // Values for the digitalRead value from gpiox button
const bool readDHT11Temp = false;
             // Values for the DHT11 digital temperature/humidity sensor
```

To use a DHT11 digital temperature and humidity sensor install the SimpleDHT library and uncommit the lines for dht11 in the Arduino Tron sensor sketch for more details and information. Change the readDHT11Temp value to true. Also, you can change the reporting time by modifying the timeCounter.

EOSPY currently supports these data fields in the Server Event data model

```
id=6 &event=allEvents &protocol=osmand &servertime=<date> &timestamp=<date>
&fixtime=<date> &outdated=false &valid=true &lat=38.85 &lon=-84.35
&altitude=27.0 &speed=0.0 &course=0.0 &address=<street address> &accuracy=0.0
&network=null &batteryLevel=78.3 &textMessage=Message_Sent &temp=71.2
&ir_temp=0.0 &humidity=0.0 &mbar=79.9 &accel_x=-0.01 &accel_y=-0.07
&accel_z=9.79 &gyro_x=0.0 &gyro_y=-0.0 &gyro_z=-0.0 &magnet_x=-0.01
&magnet_y=-0.07 &magnet_z=9.81 &light=91.0 &keypress=0.0 &alarm=Temperature
&distance=1.6 &totalDistance=3.79 &motion=false
```

You can add additional fields to the data model and transmit via any device for EOSpy AI-IoT Drools-jBPM processing. All of these values can be evaluated in the Drools Rules engine and the jBPM process.

5.3.2 AI-IoT Arduino Tron Server

The EOSPY AI-IoT Arduino Tron server software interface allows you to send commands with the EOSPY AI-IoT software to control external Arduino connected devices. The AI-IoT Arduino Tron server software uses a WiFi wireless transceiver interface to control and interact with module sensors and remote controls devices. You can control any device from the EOSpy AI-IoT Arduino Tron server software or stream any interface over the WiFi internet. With the EOSpy AI-IoT Arduino Tron server software you can automatically turn on lights, appliances, cameras, and lock/unlock doors from the Drools-jBPM Expert System processing model.

To configure the Arduino Tron server software, update the with WiFi network values for network SSID (name) and network password. Start the Arduino IDE Serial Monitor window to see what EOSpy AI-IoT Arduino Tron server code is doing via the serial connection from ESP-01 via 3.3v console cable to your PC. The EOSpy AI-IoT Arduino Tron server will report use this URL (http://) to connect address.

Set this URL address in the *eospy.properties* file *arduinoURL=http://10.0..0.2* to configure the connection to the EOSpy AI-IoT Arduino Tron server. This is the URL that all EOSpy AI-IoT Arduino Tron server commands will be transmitted from the EOSpy AI-IoT Drools-jBPM program.

You can use a command like the following to send actions to the EOSpy AI-IoT Arduino Tron server.

```
com.eospy.util.URLConnection.getInstance().sendPost("/LED3=ON");
```

The EOSpy AI-IoT Arduino Tron Server NodeMCU can receive action commands from EOSpy via HTTP URL post for 7sSeg display, relay, buzzer, infrared emitter, LED, motor actuators, gate access, auditable speech, alarms, or any other device via a HTTP URL post command.

We can use a relay in this Arduino circuit to actually switch an electoral device on and off. A relay is an electromagnetic switch, which is controlled by small current, and used to switch ON and OFF relatively a larger current. A relay is a good example of controlling the devices, using a smaller Arduino device.

Executive Order Corp will be releasing additional sketches like the LED and power relay example for use with the EOSpy AI-IoT Arduino Tron server application. Be sure to follow us on Github for future Arduino sketch and build ideas.

5.4 EOSpy AI-IoT Drools-jBPM Installation Configure

5.4.1 EOSpy AI-IoT Configure Eclipse, Drools-jBPM and BPMN2

This quick guide provides installation and configuration instructions for the EOSPY AI-IoT program, Eclipse IDE, Eclipse Plugins, Drools-jBPM and BPMN2 on your windows computer.

- Download and install the "Eclipse IDE for Java Developers."
- Use the Eclipse feature to add new software, which is available on the Eclipse menu "Help -> Install New Software". Select the "Add" option and these two packages:

  Drools + jBPM Update Site 7.7.0
  http://downloads.jboss.org/jbpm/release/7.7.0.Final/updatesite/

  BPMN2-Modeler 1.4.2
  http://download.eclipse.org/bpmn2-modeler/updates/oxygen/1.4.2/

The Executive Order Corp Arduino Tron - Arduino ESP8266 MQTT telemetry transport Machine-to-Machine (M2M) /IoT software and Arduino Tron MQTT AI-IoT Client using EOSpy AI-IoT Drools-jBPM latest software can be download from the Github website.

- Download Arduino Tron from: https://github.com/eodas/EOSpy
- GIT the EOSPY AI-IoT from the source code repository, and import existing maven project.

Once installed you can configure the different runtime properties in the *eospy.properties* file. It is easier just to uncomment the runtime environment that you intend to execute. Note: If you have an Arduino Tron_server update the arduinoURL IP address. Otherwise, just leave the arduinoURL committed.

In Eclipse, run the class EOSpy AI-IoT as a Java application. This is the main class for EOSpy AI-IoT Drools-jBPM expert system.

EOSPY Client – To install the EOSPY client application on your phone, download the EOSPY application from the Google App Store. To start the EOSPY client, click on the Eagle icon on your phone. The EOSPY client screen will appear. You can also download the EOSPY TI-SensorTag client version.

To configure a new EOSPY client you will need to enter the EOSPY server address, domain name, or IP address into the server address. Next add this device in the EOSPY server by entering the device name and the device identifier. Swipe the service status **On** and YOU'RE DONE. The device will appear on the EOSPY server map the next time the EOSPY client sends GPS position information.

GPS Tracking Devices – Many companies make various off-the-shelf GPS tracking devices. Configuring these devices will vary a little from vendors. First, add the new device with a unique identifier into the EOSPY – Executive Order Sensor Processor sYstem Server. Next, configure your device to use the appropriate EOSPY server IP address and port number. If the device fails to report, check the IP address and device ID.

Device Unique Identifier

If you don't know your device identifier you can configure your device first and look at the server log file. When the server receives a message from an unknown device it writes a record containing a unique identifier of a new device. Look for records like "Unknown device – 123456789012345"; "Unknown device" 123456789012345 is your new device identifier.

Address and Port

To select the correct port, find your device in the list of supported devices. The port column of the corresponding row contains default port numbers for your device. If you want to use variations from the default ports you can change them in the configuration file.

EOSPY supports more than 90 GPS communication protocols and more than 800 models of GPS tracking devices from popular GPS vendors. Review the list of supported devices for information about your GPS tracking device on www.eospy.com.

5.5 EOSpy AI-IoT Drools-jBPM Application Examples

5.5.1 Movement AI-IoT Drools-jBPM Artificial Intelligent Smart Automation

In the movement example, we will demonstrate how to invoke **business rules** from within our application and how to execute our jBPM processes and how to handle the interactions between **process** and **rules** using an IoT sensor device.

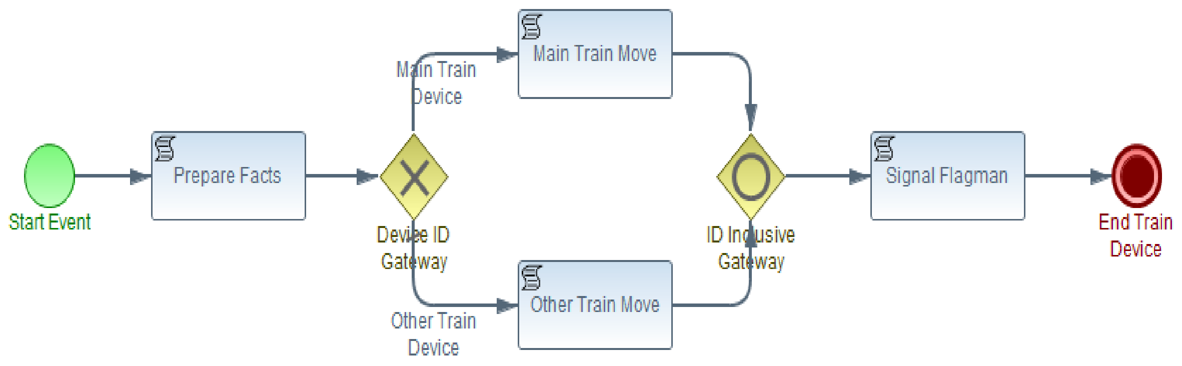
Business processes and rules are two core concepts which are defined as follows:

- **Business processes:** Represent what the business does.
- **Business rules:** Represent decisions that the business does.

Although processes and rules are two different things there is a clear advantage if your end users are allowed to combine processes and rules. This means for example:

- Rules can define which processes to invoke
- Rules can specify decisions in that process
- Rules can augment (or even override) the behavior specified in the process (for example to handle exceptional cases)
- Assignment rules can be used to assign actors to (human) tasks
- Rules can be used to dynamically alter the behavior of your process

Example 5.4.2.1. EOSpy-AI Train Movement jBPM



In this example we will use EOSpy AI-IoT Drools-jBPM to solve a knowledge and notification problem. We have a train yard with IoT devices installed on the trains to notify us if they are in motion or not. Our rule is, if none or one train is moving, the train yard signal flagman can signal that the yard is safe. If more than one train is moving, then the signal flagman signs that the trains must move slowly.

With this use of IoT Drools-jBPM analysis and reasoning in IoT devices, we were able to orchestrate dissimilar devices that normally have no awareness of each other. This creates opportunities for direct integration of computer-based into the physical world that has never been available before.

This IoT orchestration of devices give us the ability for action after our AI decision. Also, we are able to use IoT devices to update mechanical trains, giving them new awareness of each other. Of course, we could improve on our IoT Drools-jBPM application and update each train of the others proximity. This would allow us to implement collision avoidance like what is available in automobiles.

Example 5.4.2.2. Signal Train Motion Rule

```
rule "Move-Stop Train Motion Rule"
     no-loop
   when
     // event keyPress_1 used to change state Move/Stop
      $event : ServerEvent( $eventId : id, (event == "keyPress_1" || event
== "keyPress_2") )
```

```
        $device : Devices( $deviceId : id,  $eventId == id )
      then
                String result = ($device.status == "Move") ? "Stop" : "Move";
                $device.status = result;
                $device.action = "Ok";
                com.eospy.ui.MainWindow.getInstance().log("Train Device " +
    $device.getName() + " - " + result);
                modify( $device );
                update( $device );
    end
```

This rule example demonstrates the use of a pushbutton signal as a switch: each time you press the IoT button, the state is turned on (if it's off) or off (if on). This also demonstrates how we can repurpose a legacy signaling device to operate with new or different behavior.

Example 5.4.2.3. Train Motion Rules

```
    rule "More Than One Train is Moving - Slow Rule"
        when
                accumulate ( $device : Devices( $deviceId : id, $device.status
    == "Move" ); $cnt : count(1); $cnt > 1 )
    then
                com.eospy.ui.MainWindow.getInstance().log("<Slow> More Than One
    Train is Moving.");
    end
```

The train motion rules are all relatively similar, counting the number of trains reporting move status. By delegating important decisions to be taken into your rules system, the **business processes** become much more resilient to change. This IoT example provides a "**smart**" environment for the train yard or AI-IoT Drools-jBPM artificial intelligent smart automation.

The signal flagman indicates a task that needs to be executed by human actors. The Drools-jBPM business processes management human interface and system interaction for the train yard signal flagman could be a light indicator or text message telling him what to signal for the yards condition.

Drools-jBPM supports a special human task node inside processes for modeling this interaction with human users. This human task node allows process designers to define the properties related to the task that the human actor needs to execute. In our example we use a script task to execute our human task in our business process engine, for simplicity. When the task is ready to start, the engine will execute the script. When the script is completed, the task will also be completed.

With this use of IoT Drools-jBPM analysis and reasoning in IoT devices, we were able to orchestrate dissimilar devices that normally have no knowledge or awareness of each other. This demonstrates opportunities for direct integration of computer-based into the physical world that has never been available before by repurposing legacy systems or maniacal system instead of replacing the hardware.

In the movement jBPM example, the IoT device ID is used in the device ID gateway to differentiate between the main train and other train move commands. This gives us the ability to have special commands in our business process for the movement of the main train in our train yard.

We currently supports these additional data fields in the jBPM server event data model:

name, getName()	event, getEvent()
adderss, getAddress()	textMessage, getTextMessage()
temp, getTemp()	light, getLight()
keyPress, getKeypress()	alarm, getAlarm()

You can add additional fields to the data model and transmit via any device for EOSpy AI-IoT Drools-jBPM processing. All of these values can be evaluated in the Drools rules engine and the jBPM process.

5.5.2 Illuminance AI-IoT Drools-jBPM Arduino Tron Server Automation

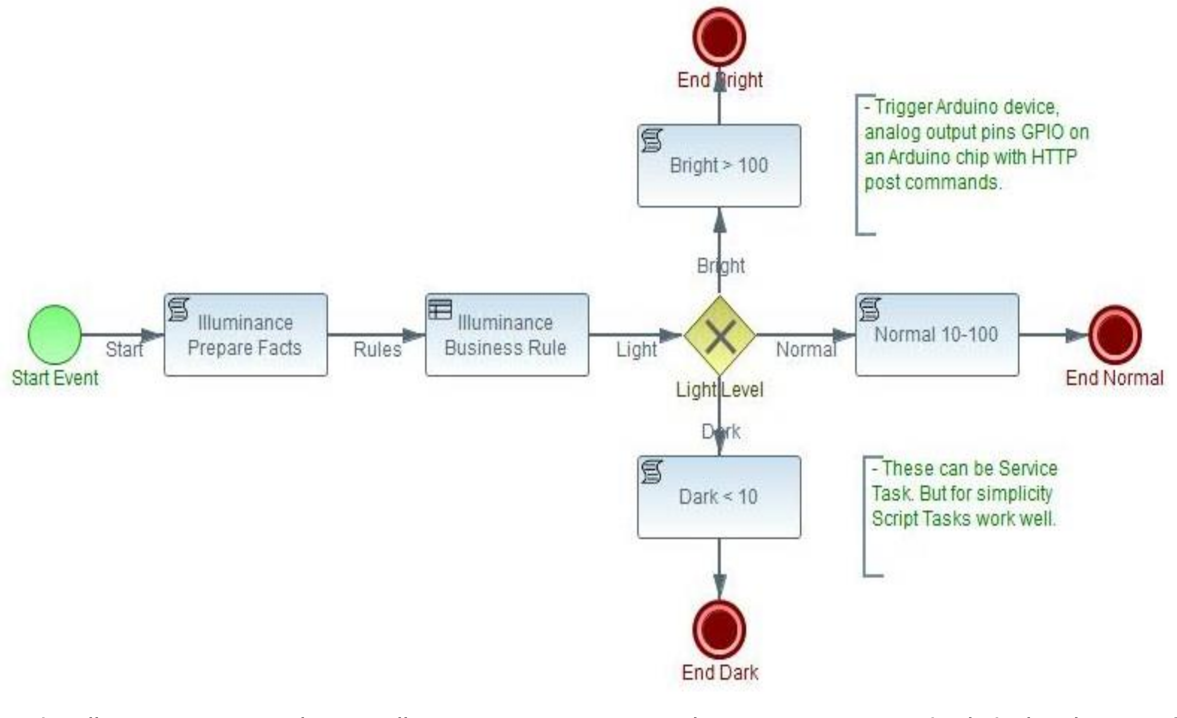
In the previous example we looked at the use EOSpy AI-IoT Drools-jBPM to solve a knowledge and notification problem. Now, let's look at an end-to-end AI-IoT Drools-jBPM example. The illuminance example, we will demonstrate how to invoke Drools **business rules** from within our jBPM executing processes and how to handle the interactions between **process** and **rules**.

We will use the EOSpy IoT client to stream remote sensor information to the EOSpy AI-IoT Drools-jBPM application. Then we will use the AI-IoT Drools-jBPM on this IoT information stream to decide what behavior and business process functions to execute. Finally, we will execute the AI-IoT Drools-jBPM decision using the EOSPY AI-IoT Arduino Tron server software interface, which allows us to send commands with the EOSPY AI-IoT software to control external Arduino connected IoT devices.

The AI-IoT Arduino Tron server software uses a WiFi wireless transceiver interface to control and interact with module sensors and remote controls devices. You can control any device from the EOSpy AI-IoT Arduino Tron server software or stream any interface over the WiFi internet. With the EOSpy AI-IoT Arduino Tron server software you can automatically turn on lights, appliances, cameras, and open doors from the Drools-jBPM Expert System processing model.

This gives us a complete IoT, to Drools-jBPM, to IoT, end-to-end process example. By streaming IoT information directly into our business process management application we can modify IoT behavior and functionality without having to physically change our IoT devices.

Example 5.5.2.1 Illuminance AI-IoT Drools-jBPM


End Bright
- Trigger Arduino device, analog output pins GPIO on an Arduino chip with HTTP post commands.
Bright > 100
Bright
Start Event
Start
Illuminance Prepare Facts
Rules
Illuminance Business Rule
Light
Light Level
Normal
Normal 10-100
End Normal
Dark
Dark < 10
- These can be Service Task. But for simplicity Script Tasks work well.
End Dark

In this illuminance example we will use EOSpy AI-IoT Drools-jBPM to manage the light level in an office. Our IoT sensor will use a photoelectric sensor to set the light field to the illuminance level. If it's too dark we want to turn on the light. If it's too bright,t we want to draw the blinds. If the light level is less than 10, we will send a signal to the lamp switch to turn on. If the light level is greater than 100, we will send a signal to the curtain motor to close the blinds.

With this use of IoT Drools-jBPM analysis and reasoning in IoT devices, we were able to orchestrate dissimilar devices that normally have no awareness of each other. This creates opportunities for direct integration of computer-based into the physical world and allow us the ability to control IoT behavior outside of the device. This allows devices to be deployed and modified or updated at any time.

After our IoT illuminance light level is read, we use the illuminance business rule group to call and execute our rules for this process. A business rule task provides a mechanism for the process to provide input to a business rules engine and to get the output of calculations that the business rules engine might provide. This rule flow group identifies the IoT device that is reporting the light level.

Example 5.4.2.2. Illuminance Rule Flow Group

```
//declare any rules to fire in the jBPM AI_IoT.Illuminance process
rule "Rule for device ID: 1"
      ruleflow-group "Illuminance Rule Flow"
      when
            $event : ServerEvent( $eventId : id, $eventId == "1" )
      then
            com.eospy.ui.MainWindow.getInstance().log("ruleflow-group device 
ID: 1 " + $event.getEvent() + " - " + $event.getName());
end
```

In the rules process class we execute a fileAllRules() prior to executing startProcess() for the jBPM.

```
// go! - fire all rules
long noOfRulesFired = this.kSession.fireAllRules();

// Start the process with knowledge session
instance = kSession.startProcess(processID, params);
```

This allows us to do some AI reasoning (discovery) prior to executing our business process. In this example, this allows us to evaluate the IoT event in updated UI display with the information.

Example 5.4.2.3. IoT Evaluate Event Rule

```
//declare rules to fire when fileAllRules() is executed
rule "Key Press 1 Rule"
    when
        $event : ServerEvent( $eventId : id, event == "keyPress_1" )
        $device : Devices( $deviceId : id,  $eventId == id )
    then
            $device.action = "Key 1";
            $device.status = "Light " + $event.getLight();
            com.eospy.ui.MainWindow.getInstance().log("Rule Key Press 1: " + 
$event.getEvent() + " - " + $event.getName() + " - " + " Light Value: " + 
$event.getLight());
            modify( $device );
end
```

Set this URL address in the *eospy.properties* file *arduinoURL=http://10.0..0.2* to configure the connection to the EOSpy AI-IoT Arduino Tron Server.

We then use a command like the following to send actions to the EOSpy AI-IoT Arduino Tron server for the Dark Script Task, where we will send a signals to the lamp switch to turn onand the Bright Script Task, where we will send a signal to the curtain motor to close the blinds.

```
com.eospy.util.URLConnection.getInstance().sendPost("/LED3=ON");
```

The EOSpy AI-IoT Arduino Tron server NodeMCU can receive action commands from EOSpy via HTTP URL post for 7 seg display, relay, buzzer, infrared emitter, LED, motor actuators, gate access, auditable speech, alarms, or any other device via a HTTP URL post command.

We can use a relay in this Arduino circuit to actually switch an electoral device on and off. A relay is an electromagnetic switch, which is controlled by small current, and used to switch ON and OFF relatively a larger current. A relay is a good example of controlling the devices, using a smaller Arduino device.

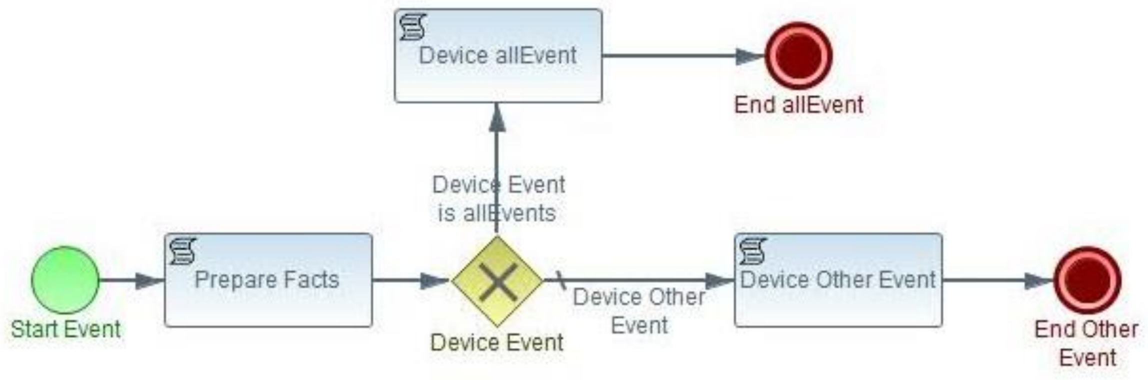
5.5.3 Gyroscope AI-IoT Drools-jBPM Motion Sensors

Depending on the device, several sensors provide information that let you monitor the motion of the device. The sensors usually include accelerometer (accel), gyroscope (gyro) and magnetometer (magnet) sensors. Motion sensors are useful for monitoring device movement, such as tilt, shake, rotation, or swing. There are also additional sensors such as gravity, linear acceleration, rotation vector, significant motion, step counter, and step detector sensors.

By processing our IoT information/data through the jBPM business process management application we can modify IoT behavior and functionality without having to physically change our IoT devices.

In the gyroscope example we will examine the IoT device magnetometer (magnet) sensors to determine if the IoT device is upside-down. This would be important information for a vehicle, shipping container, medical supplies, or any other item that could be damaged or dangerous if turned over.

Example 5.5.3.1 Gyroscope Process AI-IoT Drools-jBPM



In the jBPM process, the following we look at the IoT device event that raised our notification. This could be a significant IoT reported event like airbags deployed, fire alarm, or hazardous materials.

The gyroscope rules will examine the IoT device magnetometer (magnet) sensors and determine if the device is ‘face up’ or ‘face down’.

Example 5.4.2.3. Gyroscope IoT Evaluate Event Rule

```
//declare rules to fire in for zBias
rule "Device Gyroscope Positive zBias"
     when
   $event : ServerEvent( $eventId : id, $magnet_z : magnet_z, $magnet_z > 0 )
     $device : Devices( $deviceId : id,  $eventId == id )
     then
          $device.action = $event.getEvent();
          $device.status = "Face Up";
          modify( $device );
end
```

You can try this example and, of course, any of the others by installing the EOSPY Client Android on your phone. To install the EOSPY Client application on your phone, download the EOSPY application from the Google App Store. To start the EOSPY Client, click on the Eagle icon on your phone. The EOSPY Client screen will appear. You can also download the EOSPY TI-SensorTag Client version.

Then you can turn you phone over and watch the state change in the gyroscope rules will examine.

Also, with the IoT client device you can send custom textMessage, getTextMessage() and alarm, getAlarm() information to the EOSpy AI-IoT Drools-jBPM application for evaluation in the Drools-jBPM.

5.5.4 GPS Position AI-IoT Drools-jBPM Artificial Intelligent GPS Automation

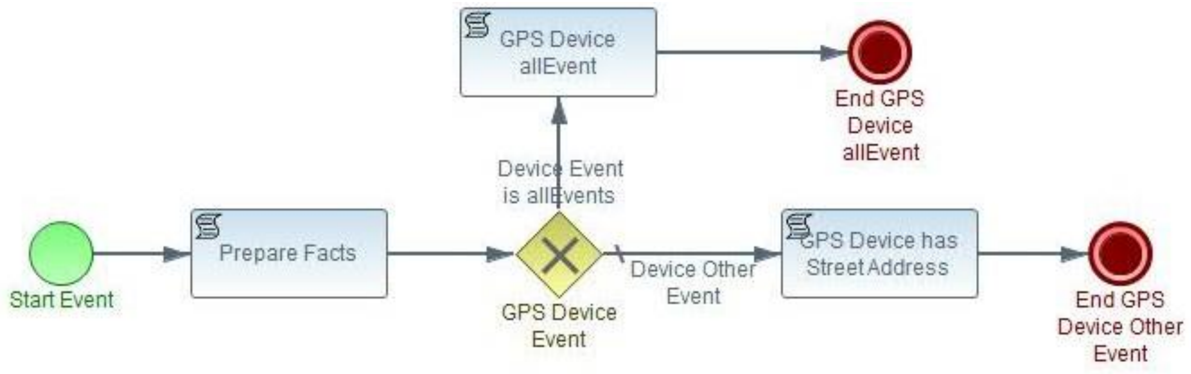
There are many IoT GPS options to choose from with EOSpy. First, you don't have to use a GPS module. If you have a fixed IoT device, consider hardcoding your GPS LAT/LON position. Then, if you have IoT device monitoring, for instance a door open, you could pin that device location to a building map. This would give you a visual indicator of the location of which door was open, or use your building blueprint.

Look at the EOSPY AI-IoT Arduino Tron sensor sketch for an example of how to can find LAT/LON from an address and hardcoding a GPS LAT/LON position-location in to the Arduino Tron application.

```
//Update these with LAT/LON GPS position values
//You can find LAT/LON from an address
https://www.latlong.net/convert-address-to-lat-long.html
String lat = "38.888160"; // position LAT
String lon = "-77.019868"; // position LON
```

The Arduino device has many options for GPS modules. The Arduino code to read information like date, time, location and satellites in view from the standard NMEA data streams. This NMEA data streams will give you the LAT/LON position to set in your lat, lon data packet.

Example 5.5.4.1 GPS Position AI-IoT Drools-jBPM



In the GPS position example jBPM process following, we examine the IoT device event that transmitted the GPS position. This could be a significant IoT event reported from the device, such as motor started, airbags deployed, overheat, outside Geofence or over-speed.

Example 5.5.4.2.GPS Position Speed Over 60 Rule

```
//declare rule to fire when Device speed is over 60
rule "GPS Device Speed Alert"
        when
          $event : ServerEvent( $eventId : id, $lat : lat, $lon : lon,
          $altitude : altitude, $speed : speed, $speed > "60" )
        $device : Devices( $deviceId : id,  $eventId == id )
        then
                $device.action = "Alert";
                $device.status = $event.getEvent();
                com.eospy.ui.MainWindow.getInstance().log($event.getName() + "
GPS Speed Alert lat:" + $lat + " lon:" + $lon + " speed:" + $speed);
                modify( $device )
end
```

This GPS position rule fires when the GPS device reported speed if greater than 60. The rule reports the position and speed that fired the rule. Depending on the GPS devices, the module can report addition information that is transmitted along with the lat, lon data packet. This information will be different depending on the device type, environment and conditions.

- **GPS Device Module Environment and Condition Rules**

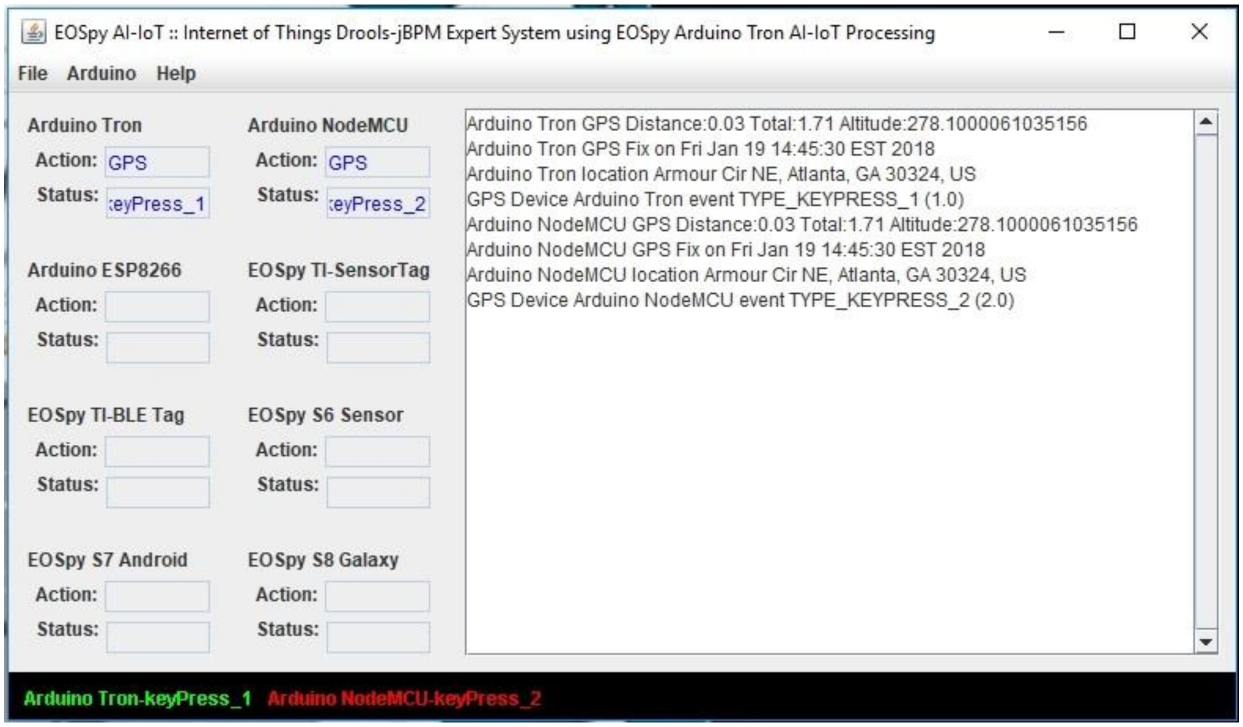
There are additional rules that respond to the GPS device, if the device sends a text messages or if the device sent an alarm.

Example 5.5.4.2.GPS Device Send Alarm

```
//declare rule to fire when GPS Device sends Alarm message
rule "GPS Device Sent Alarm"
        when
          $event : ServerEvent( $eventId : id, $alarm : alarm, $alarm != null )
        $device : Devices( $deviceId : id,  $eventId == id )
        then
                com.eospy.ui.MainWindow.getInstance().log($event.getName() + "
Sent Alarm: " + $alarm);
end
```

In addition, there are rules for processing a GPS device text message, the GPS device fix information, and GPS device address location. All of the information and messages are transmitted along in the lat, lon data packet.

Example 5.5.4.3 GPS Position AI-IoT Drools-jBPM



```
Arduino Tron GPS Distance:0.03 Total:1.71 Altitude:278.1000061035156
Arduino Tron GPS Fix on Fri Jan 19 14:45:30 EST 2018
Arduino Tron location Armour Cir NE, Atlanta, GA 30324, US
GPS Device Arduino Tron event TYPE_KEYPRESS_1 (1.0)
Arduino NodeMCU GPS Distance:0.03 Total:1.71 Altitude:278.1000061035156
Arduino NodeMCU GPS Fix on Fri Jan 19 14:45:30 EST 2018
Arduino NodeMCU location Armour Cir NE, Atlanta, GA 30324, US
GPS Device Arduino NodeMCU event TYPE_KEYPRESS_2 (2.0)
```

In the GPS position example, we can see the rules for GPS device distance, GPS device fix information, and GPS device address location being fired. If the GPS module transmitted addition information in the &alarm= or &textMessage= fields, then those rules would fire.

The jBPM Script Task node; GPS Device has street address runs a conditional Java script task.

```
log("GPS Device " +  kcontext.getVariable("name") + " event TYPE KEYPRESS 2 (2.0)");
```

A script task is executed by a business process engine. The modeler or implementer defines a script in a language that the engine can interpret. When the task is ready to start, the engine will execute the script. When the script is completed, the task will also be completed.

Script tasks can run action tasks and very complex evaluations, and are convenient for combining data.

- **Android Things System on Module (SoM)**

Android things lets you build professional, mass-market products on a trusted platform, without previous knowledge of embedded system design. It reduces the large, upfront development costs and the risks inherent in getting your idea off the ground.

Android things hardware provides a turnkey hardware platform to build your IoT device. Android certified development boards based on System on Module (SoM) architecture give you the following benefits to get you started quickly:

- Integrated Parts - SoMs integrate the SoC (System-on-Chip), RAM, flash storage, WiFi, Bluetooth and other components onto a single board and come with all of the necessary FCC certifications. When you want to mass produce your device, you can optimize your board design by flattening existing modules onto a PCB to save costs and space.
- A Google BSP - The Board Support Package (BSP) is managed by Google, therefore, that means you don't have to do kernel or firmware development. This gives you a trusted platform to develop on with standard updates and fixes from Google.
- Differentiated hardware - Our partners provide development boards with different SoMs and form factors to suit your needs, giving you choice and flexibility. And when you're ready, take your prototypes to products by customizing them to fit a specific form-factor, all while running the same software.

Android things SDK extends the core Android framework with additional APIs provided by the things support library, which lets you integrate with new types of hardware not found on mobile devices.

Developing apps for embedded devices is different from mobile in a few important ways such as:

- More flexible access to hardware peripherals and drivers than mobile devices
- System apps are not present to optimize startup and storage requirements
- Apps are launched automatically on startup to immerse your users in the app experience.
- Devices expose only one app to users, instead of multiple like with mobile devices

- **GPS Tracking Devices**

Many companies make various off-the-shelf GPS Tracking devices. Configuring these devices will vary a little from vendors. First, add the new device with a unique identifier into the EOSPY – Executive Order Sensor Processor sYstem Server. Next, configure your device to use the appropriate EOSPY Server IP address and port number. If the device fails to report, check the IP Address and Device ID.

Device Unique Identifier - For most devices you should use an IMEI (International Mobile Equipment Identity) number as a unique identifier. However, some devices have vendor specific unique identifiers, for example TK-103 devices use 12-digit identifier.

If you don't know your device identifier you can configure your device first and look at the server log file. When the server receives a message from an unknown device it writes a record containing a unique identifier of a new device. Look for records like "Unknown device – 123456789012345"; "Unknown device" 123456789012345 is your new Device identifier.

Address and Port - To select the correct port, find your device in the list of supported devices. The port column of the corresponding row contains default port numbers for your device. If you want to use variations from the default ports you can change them in the configuration file.

EOSPY supports more than 90 GPS communication protocols and more than 800 models of GPS tracking devices from popular GPS vendors. Review the list of supported devices for information about your GPS Tracking Device.

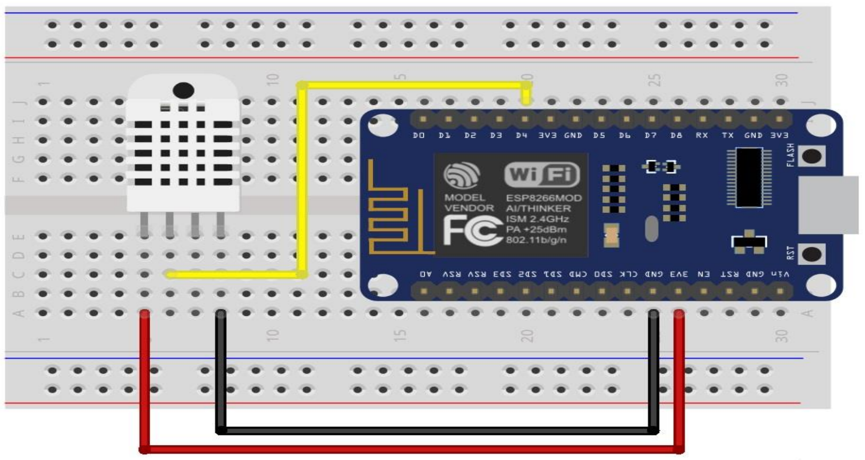
EOSpy live map server will display additional sensors data you provide that you need to automate your processes and gain visibility into your business operations. This additional data could be: ambient temperature, IR object temperature, humidity sensor, pressure sensor, ambient light, accelerometer, gyroscope, magnetometer, digital microphone, magnetic sensor, and magnetometer.

5.5.5 Environment AI-IoT Drools-jBPM Artificial Intelligent Sensor Automation

In the previous examples we looked at the use EOSpy AI-IoT Drools-jBPM to solve a knowledge and notification problem, and looked at an end-to-end AI-IoT Drools-jBPM example. We have demonstrated how to invoke Drools **business rules** from within our jBPM executing processes and how to handle the interactions between **process** and **rules**. These applications work with both EOSPY Android and the EOSPY Arduino Tron application installed on your Arduino IoT Device. Now let's look at a board build Arduino Tron IoT reasoning device. This Arduino Tron device is an Industrial Internet of Things (IIoT) or Machine to Machine (M2M) device that uses sensors in the build with the Arduino device.

We will use the Arduino ESP8266 ESP-01S WiFi serial transceiver module with 4MB flash for Arduino provides very inexpensive **IoT MQTT** telemetry transport platform. Download the EOSPY Arduino Tron sensor application from GIT. Update the with WiFi network values for network SSID (name) and network password. Update the EOSPY server IP address and unique unit ID values and add in EOSPY server. Also, we will use a DHT11 digital temperature and humidity sensor see the Arduino Tron sensor sketch for more details and information.

Example 5.5.5.1 Environment Reasoning DHT Board Schematic



This is the schematic you need to wire the DHT sensor to your ESP8266 board. We will use the EOSpy IoT client to stream remote Arduino ESP8266 DHT11/DHT22 temperature and humidity sensor information to the EOSpy AI-IoT Drools-jBPM application. Then we will use the AI-IoT Drools-jBPM on this IoT information stream to decide what behavior and business process functions to execute.

All the fields you have provided values for so far are for WiFi communications, the remaining fields are used in the Arduino Tron sensor application. To use a DHT11/DHT12 digital temperature and humidity sensor see the Arduino Tron sensor sketch for more details and information.

```
const bool readPushButton = true;
                    // Values for the digitalRead value from gpiox button
const bool readDHT11Temp = false;
             // Values for the DHT11 digital temperature/humidity sensor
```

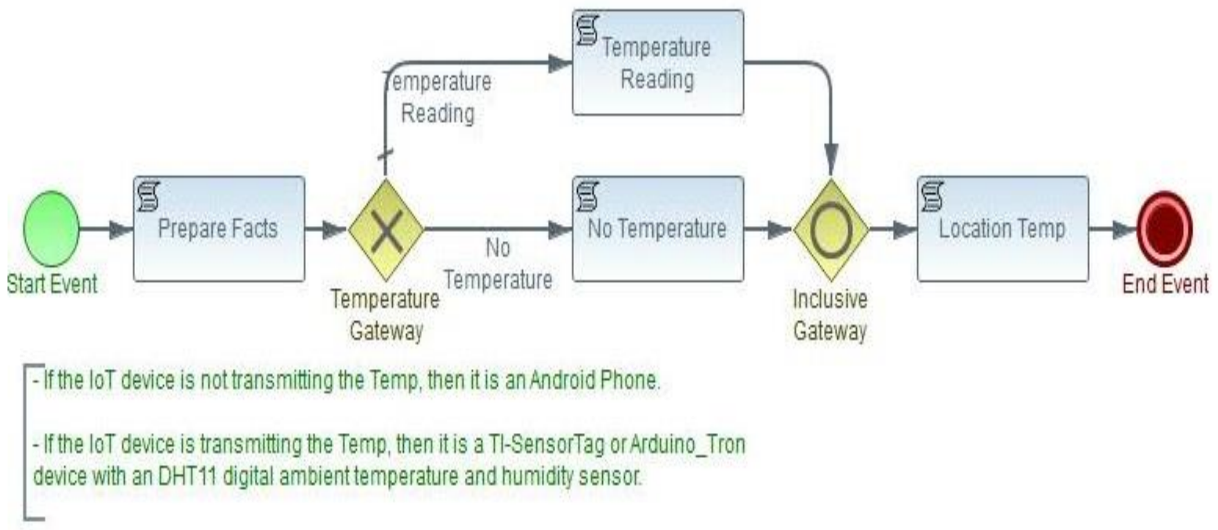
To use a DHT11 digital temperature and humidity sensor install the SimpleDHT library and uncommit the lines for dht11 in the Arduino Tron sensor sketch for more details and information. Change the readDHT11Temp value to true. Also, you can change the reporting time by modifying the timeCounter that calls the Arduino Tron sensor sketch function for reading the DHT11.

```
void readdht11(); // read DHT11 digital temperature and humidity sensor
```

Remember to uncommit all the lines for the dht11 in the Arduino Tron sensor sketch.

```
if ((err = dht11.read(pinDHT11, &temperature, &humidity, NULL)) !=
SimpleDHTErrSuccess) { <-- uncommit for dht11
```

Example 5.5.5.2 Environment Reasoning AI-IoT Drools-jBPM


Start Event
Prepare Facts
Temperature Gateway
Temperature Reading
Temperature Reading
No Temperature
No Temperature
Inclusive Gateway
Location Temp
End Event
- If the IoT device is not transmitting the Temp, then it is an Android Phone.
- If the IoT device is transmitting the Temp, then it is a TI-SensorTag or Arduino_Tron device with an DHT11 digital ambient temperature and humidity sensor.

In the environment reasoning example jBPM process following, we examine the IoT device temperature event that is transmitted by the Arduino device. Also, we evaluate any significant IoT reported temperature or humidity event such as; too warm or too cold condition at our location.

Example 5.5.5.3.Enviorment Reasoning Raise alarm - Too Warm at Location

```
//declare rule to fire when Temp is over 75
rule "Raise alarm - Too Warm at Location"
    when
      $event : ServerEvent( $eventId : id, $temp : temp, $temp > "75" )
     $device : Devices( $deviceId : id,  $eventId == id )
    then
         $device.action = "Alert";
         $device.status = "Temp " + $temp;
         com.eospy.ui.MainWindow.getInstance().log(">>Raise Temp Alarm "
+ $event.getName() + " Temperature:" + $temp);
         modify( $device );
end
```

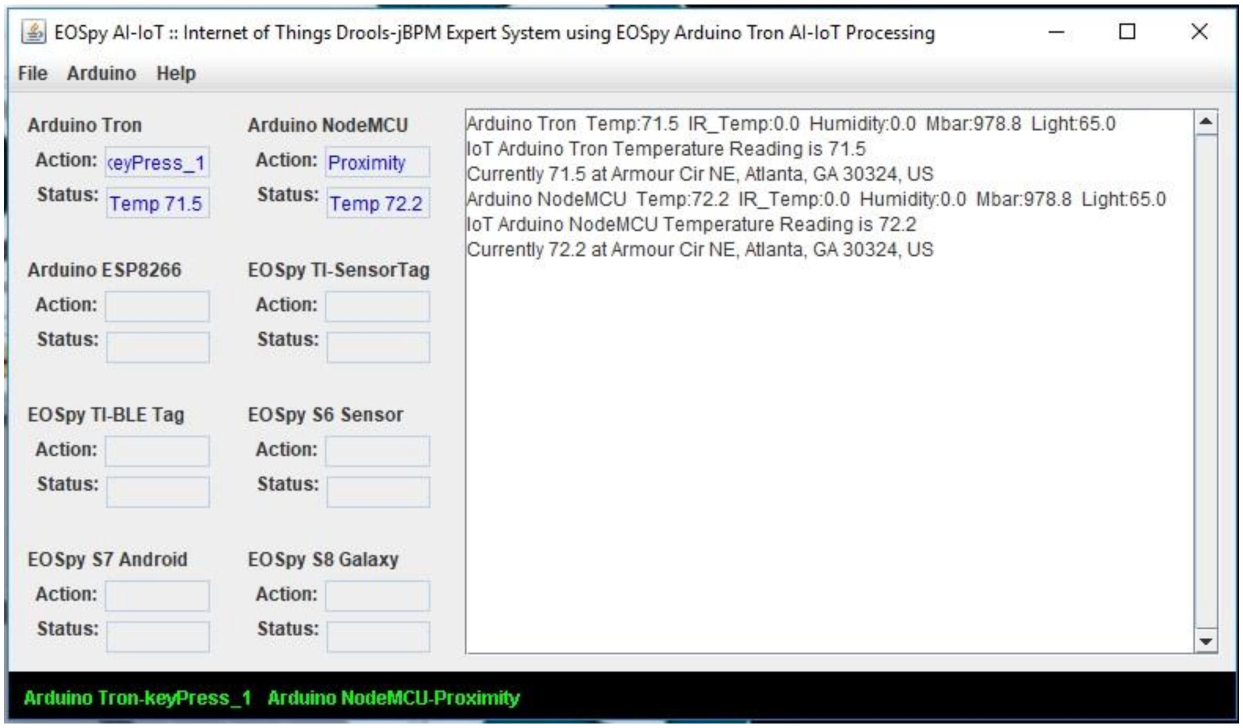
This environment reasoning rule fires when the DHT11 device reports a temperature if greater than 75. A GPS device module can be added to our environment and condition rules, the rule then reports the position and temperature when the rule is fired. Depending on the GPS devices, the module can report addition information that is transmitted along with the lat, lon data packet. There are additional rules that respond to the GPS device, if the device sends a text messages or if the device sent an alarm.

Example 5.5.5.4.Enviorment Reasoning Device Send Text Message

```
//declare rule to fire when GPS Device sends Alarm message
rule "IoT Device Sent Text Message"
    when
      $event : ServerEvent( $eventId : id, $textMessage : textMessage,
$textMessage != null )
     $device : Devices( $deviceId : id,  $eventId == id )
    then
         com.eospy.ui.MainWindow.getInstance().log($event.getName() + "
Text Message: " + $textMessage);
end
```

In addition, there are rules for processing an IoT device text message, the IoT device fix information, and IoT device address location, with current temperature at this address location.

Example 5.5.5.4 Environment Processing AI-IoT Drools-jBPM



Arduino Tron — Action: keyPress_1 — Status: Temp 71.5

Arduino NodeMCU — Action: Proximity — Status: Temp 72.2

```
Arduino Tron  Temp:71.5  IR_Temp:0.0  Humidity:0.0  Mbar:978.8  Light:65.0
IoT Arduino Tron Temperature Reading is 71.5
Currently 71.5 at Armour Cir NE, Atlanta, GA 30324, US
Arduino NodeMCU  Temp:72.2  IR_Temp:0.0  Humidity:0.0  Mbar:978.8  Light:65.0
IoT Arduino NodeMCU Temperature Reading is 72.2
Currently 72.2 at Armour Cir NE, Atlanta, GA 30324, US
```

Arduino Tron-keyPress_1 Arduino NodeMCU-Proximity

IoT devices can be accessed anywhere in the world via internet and exchange all types of data. In this example we are exploiting only one sensor located somewhere else in the world. The NodeMCU ESP8266 microcontroller has hundreds of various sensors available for the Arduino boards.

Additionally, the Arduino data can be stored in the memory for later import in our application for processing. This type of store and forward connectivity is useful when the sensors are out of WiFi range. The NodeMCU is a very powerful and economic platform. The attractiveness lies within the fact that this microcontroller board can be programmed via the Arduino IDE with familiar Arduino instructions.

5.6 Summary

IoT devices opens an opportunity to create a new generation of business processes that can benefit from IoT integration, taking advantage of networking, sensing capabilities, remote awareness, and the ability to take action. The jBPM-BPMN modular allow us to define both the business processes and IoT devices behavior at the same time using one diagram. This allows us to define IoT behavior within business process and with the same level of abstraction of other atomic actions or events in our standard jBPMN. Additionally, this adds the ability for remote reprogramming facilitates code deployment and adds support for dynamic ad-hoc business process changes.

In the example we have seen, Drools stream mode for Complex Event Processing for solving complex IoT event reasoning problems. Events in Drools are immutable objects with strong time-related relationships. CEP has a great value, especially if we need to make complex decisions over a high number of events.

This example also discussed the Drools type declarations which can define metadata on top of the existing types or define new types. As was demonstrated, new types are useful for rule decomposition.

Follow EOSpy website www.eospy.com for additional information on EOSpy-AI

6 Arduino Tron Lite Streaming AI-IoT Drools-jBPM

6.1 Arduino Tron Lite Streamline AI-IoT Drools-jBPM

6.1.1 Arduino Tron IoT AI-Artificial Intelligent Lite Streamline Automation

The Arduino Tron allows you to send IoT sensor data information directly to the AI-IoT Drools-jBPM Expert System from any Arduino device. This provides a very lite streamline IoT to Drools-jBPM (Business Process Management) application process without the GPS LAT/LON, speed, bearing, and altitude positioning information. This makes for a very efficient IoT Drools-jBPM Expert System.

If you have fixed IoT sensors monitoring conditions and environment or IoT devices that operate equipment, then the Arduino Tron is all that is needed. The IoT devices WiFi their information directly to the Arduino Tron Server. The Arduino Tron Server then process the IoT data through the Drools Inference Engine and the jBPM process model.

With Arduino Tron jBPM-BPMN modular it allows us to define both the business processes and IoT devices behavior at the same time using one diagram. With Arduino Tron adding just Drools-jBPM to IoT, we make the IoT devices "smart". This technique also helps Drools to process a large number of objects more efficiently and is designed for high volumes of data.

This quick section will help you install and configure the Arduino Tron – Executive Order Sensor Processor System components.

Executive Order Arduino Tron has several components to provide a complete AI-IoT system:

- **Arduino Tron AI-IoT (Java):** Internet of Things Drools-jBPM Expert System.
- **Arduino Tron Sensor (Arduino):** Application to send sensor MQTT Telemetry Transport.
- **Arduino Tron Server (Arduino):** Software to control external Arduino connected devices.

You can have an unlimited number and combination of Arduino Tron IoT Devices and/or EOSPY GPS Client tracking devices in use with Arduino Tron AI-IoT.

(Optionally, you can download EOSPY server from our website http://www.eospy.com and Download EOSPY GPS client from the Google Store, standard or TI-SensorTag version.)

6.1.2 Arduino Tron AI-IoT Configure Eclipse, Drools-jBPM and BPMN2

This quick guide provides installation and configuration instructions for the Arduino Tron AI-IoT program, Eclipse IDE, Eclipse Plugins, Drools-jBPM and BPMN2 on your windows computer.

- Download and install the "Eclipse IDE for Java Developers."
- Use the Eclipse feature to add new software, which is available on the Eclipse menu "Help -> Install New Software". Select the "Add" option and these two packages:

  Drools + jBPM Update Site 7.7.0
  http://downloads.jboss.org/jbpm/release/7.7.0.Final/updatesite/

  BPMN2-Modeler 1.4.2
  http://download.eclipse.org/bpmn2-modeler/updates/oxygen/1.4.2/

The Executive Order Corp Arduino Tron - Arduino ESP8266 MQTT telemetry transport Machine-to-Machine (M2M) /IoT software and Arduino Tron MQTT AI-IoT Client using EOSpy AI-IoT Drools-jBPM latest software can be download from the Github website.

- Download Arduino Tron from: https://github.com/eodas/ArduinoTron
- GIT the Arduino Tron AI-IoT from the source code repository, and import existing maven project into Eclipse IDE project.

Once installed you can configure the different runtime properties in the *arduinotron.properties* file. It is easier just to uncomment the runtime environment that you intend to execute.

Note: If you have an Arduino_Tron_Sensor update the arduinoURL IP address. Otherwise, just leave the arduinoURL committed to bypass this operation.

In Eclipse, run the class ArduinoTron as a Java application. This is the main class for ArduinoTron AI-IoT Drools-jBPM expert system.

6.2 Arduino Tron IoT Prototype Sensor Emulator

6.2.1 Arduino Tron Sensor Send MQTT Telemetry Transport IoT Data

The Arduino Tron MQTT sensor software allows you to interface and send MQTT telemetry transport information from your external connected Arduino devices to the Arduino Tron AI-IoT Drools-jBPM server. The AI-IoT Arduino Tron server software uses a WiFi wireless transceiver interface to stream telemetry information to the Arduino Tron server for any control module sensors or remote control connected Arduino device.

Arduino Tron Sensor – To install the Arduino Tron application on your Arduino device, download the Arduino Tron Sensor application from GIT. Update the with WiFi network values for network SSID (name) and network password. Update the Arduino Tron Server IP address and unique unit ID values. Also, you may use a DHT11 digital temperature and humidity sensor (see the Arduino Tron Sensor sketch for more details and information).

Arduino Tron IoT Sensor Emulate - Prototype an Arduino-based low-power WiFi Internet of Things (IoT) device with built-in sensors emulation that could be used to deliver sensor data from any location in the world, and potentially control connected devices such as thermostats, lights, door locks, and other automation products. Use a serial monitor to emulate sensor input values to Arduino Tron. This will allow you to prototype the final IoT device before custom-designing PCB-printed circuit board.

6.2.2 Arduino Tron Server Control External Arduino Connected Devices

The Arduino Tron server software interface allows you to send commands with the Arduino Tron AI-IoT server software to control external Arduino connected devices. The Arduino Tron AI-IoT server software uses a WiFi wireless transceiver interface to control and interact with module sensors and remote controls devices.

You can control any device from the Arduino Tron server software or stream any interface over the WiFi internet. With the Arduino Tron server software you can automatically turn on lights, appliances, cameras, and lock/unlock doors from the Drools-jBPM expert system processing.

Arduino Tron Server - To install the Arduino Tron application on your Arduino Device, download the Arduino Tron Server application from GIT.

6.3 Summary

The Arduino Tron AI-IoT Drools-jBPM Expert System provides sophisticated jBPM and drools processing. Arduino Tron provides a very lite streamline IoT to Drools-jBPM (Business Process Management) application process without the GPS data overhead.

The jBPM-BPMN modular allow us to define both the business processes and IoT devices behavior at the same time using one diagram. This allows us to define IoT behavior within business process and with the same level of abstraction of other atomic actions or events in our standard jBPMN.

For fixed IoT sensors monitoring conditions and environment or IoT devices that operate equipment, then the Arduino Tron is all that is needed. The IoT devices WiFi's their information directly to the Arduino Tron Server. The Arduino Tron Server then process the IoT data through the Drools Inference Engine and the jBPM process model.

The Arduino Tron IoT Sensor Emulate allows you to prototype an Arduino IoT sensor device without building the final IoT device before custom-designing PCB-printed circuit board. Use a serial monitor to emulate sensor input values to Arduino Tron. You can also add additional fields to the data model and transmit via any device to the Arduino Tron Drools-jBPM processing model.

7 EOSpy AI-IoT Internet of Things Resource Constraint Solver

7.1 EOSpy AI-IoT OptaPlanner Constraint Solver Reasoning

7.1.1 OptaPlanner AI-IoT Smart Automation Constraint Solver

OptaPlanner is a constraint solver. It optimizes business resource planning use cases, such as vehicle routing, employee rostering, cloud optimization, task assignment, job scheduling, bin packing and many more. Every organization faces such scheduling obstacles: assign a limited set of constrained resources (employees, assets, time and money) to provide products or services. OptaPlanner delivers more efficient plans to improve service quality and reduce costs.

OptaPlanner is a lightweight, embeddable planning engine. It enables normal Java programmers to solve optimization problems efficiently. It is also compatible with other JVM languages (such as Kotlin and Scala). Constraints apply on the plain domain objects and can reuse existing code. There’s no need to input them as mathematical equations. Under the hood, OptaPlanner combines sophisticated optimization heuristics and metaheuristics (such as Tabu search, simulated annealing and late acceptance) with very efficient score calculation.

7.2 EOSpy-AI Resource Problem Description

Let's consider solving a technician resource assignment problem for our business requirement in our EOSpy-AI Internet of Things System. Our business model will have technicians out in the field and we will receive trouble tickets. Our customers have different levels of service. We want to route our technicians to the customers with the highest revenue potential to maximize our business profits.

One of the characteristics is the calculation of the solution score using the rules engine. It means that we define our problem constraints implementing business rules and assigning a score to each one, making it easy to implement and scale our trouble ticket with customer service level requirements. You have technicians with different skill levels, therefore, you don’t want to assign a high skill level technician to a lower skill level ticket or to a customer that is receiving large discounts.

7.3 EOSpy-AI Solving Resource Assignment Problem

EOSpy-AI will solve the resource assignment problem using the Tabu search acceptor. In our Drools EOSpy-AI example you have a company that provides technicians with different skills to customers based on the skills, location, and availability of the technicians, and you want to automatically choose the best technician for every trouble ticket request. Additionally, you have customers with varying service charge rates. Also, we want to route your technicians to the customers with the highest revenue potential to maximize your business profits. This may mean passing a closer lower level customer to travel to a higher charge customer because we can bill the tech at a higher rate.

7.4 EOSpy OptaPlanner AI-IoT Planning Engine

The OptiPlanner is a **lightweight, embeddable planning engine that optimizes planning problems** and well suited for both EOSpy-AI CLOUD-based and STREAM-based AI-IoT problems.
It solves use cases such as:

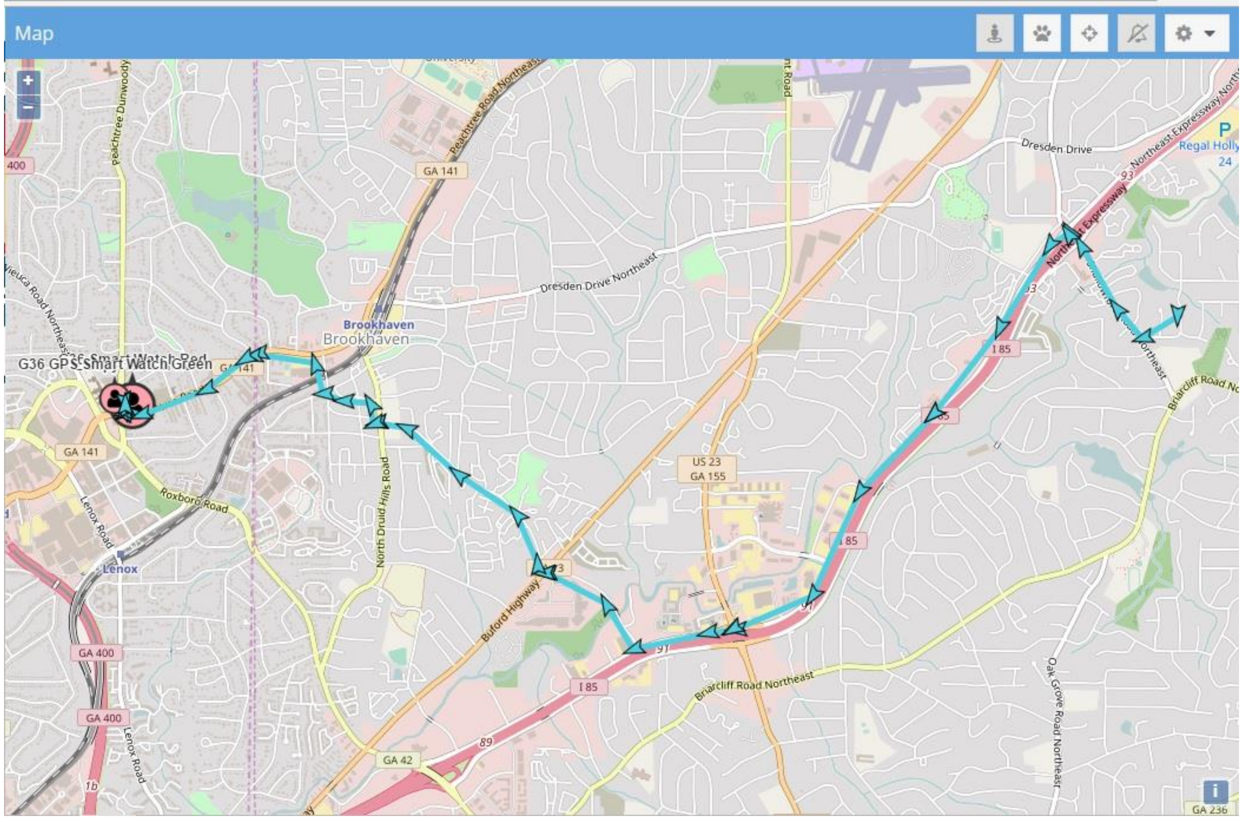
- **Employee shift rostering**: timetabling nurses, repairmen, technician (GPS)
- **Agenda scheduling**: scheduling meetings, appointments, maintenance jobs, advertisements
- **Employee timetabling**: scheduling lessons, courses, exams, conference presentations
- **Vehicle routing**: planning vehicles (trucks, trains, boats, airplanes (with freight and/or people)
- **Bin packing**: filling containers, trucks, ships / storage warehouses, and cloud computer nodes
- **Job scheduling**: planning car assembly lines, machine queue planning, workforce planning
- **Tracking stock**: minimizing waste, asset tracking, rental/lease tracking (item GPS tracking)

Every organization faces planning problems - Provide products and services with a limited set of constrained resources (employees, assets, time and money).

The OptiPlanner module is used to optimize automated planning problems combining search algorithms with the core of the rules engine. It can be used to solve lots of different use cases such as scheduling, routing, timetables and receive the IoT GPS information from our EOSpy IoT clients from our service technicians in the field.

The OptiPlanner provides a bench marker that is useful to find the solver type that best fits in your problem domain. It will help you in the process of comparing the performance of solvers creating reports with statistics and information that we can use to tweak the configurations.

OptiPlanner supports several optimization algorithms to efficiently wade through that incredibly large number of possible solutions. Depending on the use case, some optimization algorithms perform better than others. You can switch the optimization algorithm by changing the solver configuration.



Example 6.4.1. EOSpy-AI best solution found planner route

IoT Streaming Event Correlation Map Analysis

- The goal for streaming event correlation layer is to leverage topology/service model insights and provide a correlated status mapping of the IoT smart things sensors and data.
- IoT sensors and monitors will listen to queues and fetch common event objects produced by the data ingestion layer and insert them into JBoss BRMS Drools as "facts" and the @role metadata tag to the fact type: "events" and map conditions accordingly on the EOSpy map.
- JBoss BRMS (based on RETE algorithm and forward chaining) shall, in-real time, evaluate the appropriate business rules that need to get fired based on the appropriate IoT conditions.

7.4.1 EOSpy-AI class explanation

In EOSpy-AI we will need resource assignment of technicians with different *skills* and *training levels* to service a trouble ticket request. Define the *Skill*, *Location* and *Training Level* enum class definition sets.

7.4.2 Technician Java class explanation

In the EOSpy-AI Drools expert system, the Technician Java class is defined as followings.

Example 6.4.2.1. Java Technician class definition

```
package com.eospy.ai_iot;

public class Technician {
	private Location location;
	private TrainingLevel trainingLevel;
	private boolean busy;
	private Set<Skill> skills;

	public Technician(Location location, TrainingLevel training, boolean busy,
Set<Skill> skills) {
		this.location = location;
		this.trainingLevel = training;
		this.busy = busy;
		this.skills = skills;
	}

	public Technician(Technician technician) {
		this(technician.location,
		technician.trainingLevel,
		technician.busy,
		(technician.skills.isEmpty()) ? Collections.<Skill> emptySet() :
technician.skills);
}
```

7.4.3 Service Request Java class explanation

In the EOSpy-AI system the last class is the service request or trouble ticket. The service request will specify the required skills and desired location of the requested technician. This class must be annotated with a *@PlanningEntity* annotation, which is discussed in detail next.

Example 6.4.3.1. Service Request class definition

```
package com.eospy.ai_iot;

@PlanningEntity
public class ServiceRequest {
	private Location location;
	private Set<Skill> neededSkills;
	private Technician technician;

	public ServiceRequest(Location location, Set<Skill> neededSkills) {
		this.location = location;
		this.neededSkills = neededSkills;
	}

	public ServiceRequest(ServiceRequest serviceRequest) {
		this(serviceRequest.location, EnumSet.
copyOf(serviceRequest.neededSkills));
		if (serviceRequest.technician != null) {
				setTechnician(new Technician(serviceRequest. technician));
		}
	}
```

```
@PlanningVariable
@ValueRangeFromSolutionProperty(propertyName = "serviceRequests")
```

With our EOSpy-AI domain model defined, we can start creating the classes needed by OptiPlanner. The TechnicianMove class, which must implement the drools.planner move interface, and generate the changes between different solutions.

The *ServiceRequest* entity class was annotated with the *@PlanningEntity* annotation. The planning entity is a POJO that changes during the solving phase. In our EOSpy-AI example, only the *ServiceRequest* property values will change during the execution of the planning steps.

The properties of the planning entities that change during planning must be annotated with the *@PlanningVariable* annotation and also must specify that the values range using one of the following available annotations, which are pretty descriptive:

```
	@ValueRangeFromSolutionProperty(propertyName = "propertyNameInSolution")
	@ValueRangeFromPlanningEntityProperty(propertyName = "propertyNameInEntity")
	@ValueRangeUndefinied
```

The class that implements the drools.planner move interface, is where the EOSpy-AI OptiPlanner concepts come into light. It will represent a change from a solution A to a solution B, but to understand a little more you have to know that local search solves a problem by making a move on the current solution that changes it into a better solution, acting very much like a human:

Example 6.4.4.1. Java Technician Move class definition

```
package com.eospy.ai_iot;

public class TechnicianMove implements Move {
	private ServiceRequest serviceRequest;
	private Technician technician;

	public TechnicianMove(ServiceRequest serviceRequest, Technician technician) {
		this.serviceRequest = serviceRequest;
		this.technician = technician;
	}

	@Override
	public boolean isMoveDoable(WorkingMemory wm) {
		return !serviceRequest.getTechnician().equals(technician);
	}

	@Override
	public Move createUndoMove(WorkingMemory wm) {
		return new TechnicianMove(serviceRequest,
serviceRequest.getTechnician());
	}

	@Override
	public void doMove(WorkingMemory wm) {
			FactHandle serviceRequestHandle =
wm.getFactHandle(serviceRequest);
			serviceRequest.setTechnician(technician);
			wm.update(serviceRequestHandle, serviceRequest);
	}
}
```

The *isMoveDoable(WorkingMemory)* method is automatically used by OptiPlanner to filter the non-doable moves. A non-doable method is:

- A move that changes nothing on the current solution
- A move that is impossible to do on the current solution

In a non-doable move is when the move wants to assign the same technician to a service request who is already assigned in the current solution. Next, you will see a implementation of the *isMoveDoable(WorkingMemory)* method:

```
@Override
public boolean isMoveDoable(WorkingMemory workingMemory) {
      return !serviceRequest.getTechnician().equals(technician);
}
```

OptiPlanner also needs to know how to undo the last move, by simply implementing the *createUndoMove(WorkingMemory)* method, which is shown as:

```
@Override
public Move createUndoMove(WorkingMemory workingMemory) {
      return new TechnicianMove(serviceRequest, serviceRequest.getTechnician());
}
```

EOSpy-AI should know how to create a new move by calling the *doMove(WorkingMemory)* method. Inside this method it assigns the current technician to the service request and update working memory:

```
@Override
public void doMove(WorkingMemory workingMemory) {
      FactHandle serviceRequestHandle =
workingMemory.getFactHandle(serviceRequest);
      serviceRequest.setTechnician(technician);
      workingMemory.update(serviceRequestHandle, serviceRequest);
}
```

Next is the generation of EOSpy-AI moves. At this moment we can only do a single move, but we need to generate a move set. It's up to you and your business case, but you will have to create a move set that can be sequentially combined to reach all the possible solutions.

The move set is generated with a *MoveFactory* implementation. We used a *CachedMovefactory* and implemented the *createCachedMoveList(Solution)* method to generate the move set. Inside this method, we generated a move for each of the requested services with all the available technicians, generating a full move set with all the possible combinations:

```
package com.eospy.ai_iot;

public class SelectNextTechnicians extends CachedMoveFactory {
      @Override
      public List<Move> createCachedMoveList(Solution solution) {
            TechniciansSolution techSolution = (TechniciansSolution) solution;
            List<Move> moves = new ArrayList<Move>();
            for (ServiceRequest sr : techSolution.getServiceRequests()) {
                  for (Technician technician : techSolution.getTechnicians()) {
                        moves.add(new TechnicianMove(sr, technician));
                  }
            }
            return moves;
      }
}
```

Now that EOSpy-AI has generated the move set, we have to implement the *Solution* interface using the *SimpleScore* object. The *SimpleScore* object will contain the score of the current solution, which is calculated / recalculated after each step execution, and the best solution found after the execution will be the one with the highest score.

The solution was implemented for EOSpy-AI example using a *SimpleScore* score implementation:

```
package com.eospy.ai_iot;

public class TechniciansSolution implements Solution<SimpleScore> {
	private List<Technician> technicians;
	private List<ServiceRequest> serviceRequests;
	private SimpleScore score;

	public TechniciansSolution(List<Technician> technicians, List<ServiceRequest>
serviceRequests) {
		this.technicians = technicians;
		this.serviceRequests = serviceRequests;
	}

@Override
	public Solution<SimpleScore> cloneSolution() {
		TechniciansSolution solution = new TechniciansSolution();
			solution.score = score;
			solution.technicians = technicians;
			List<ServiceRequest> clonedServices = new
ArrayList<ServiceRequest>(serviceRequests.size());
			for (ServiceRequest sr : serviceRequests) {
				clonedServices.add(new ServiceRequest(sr));
			}
			solution.serviceRequests = clonedServices;
			return solution;
	}
}
```

7.4.4 EOSpy-AI Technician Rules explanation

In EOSpy-AI the score calculation is done using score rules, which makes the process of adding more constraints relatively easy and scalable. The *scoreCalculator* global will be automatically inserted into the working memory and has to be used to calculate the score of the current step. Ideally, this score has to be updated in a single rule using the weights generated by the score rules.

In EOSpy-AI, we can find several constraints, and one such constraint is that ideally the technician must be in the same location as the service request. In the rule consequence, we need to logically insert a new *IntConstraintOcurrence* fact with a value. In this case the value should be 1, to specify the weight of the broken constraint:

Example 6.4.4.1. Technician Rules definition

```
	rule "sameCity"
	    when
	        $sd : ServiceRequest(technician.location != location)
	    then
	        insertLogical(new IntConstraintOccurrence("sameCity", 1, $sd));
	end
```

Another constraint is the technician availability, which must be available to potentially be selected as the best solution. In this rule consequence, we assigned a higher weight than the previous rule constraint because it has more importance:

```
rule "isBusy"
    when
        $sd : ServiceRequest(technician.busy == true)
    then
        insertLogical(new IntConstraintOccurrence("isBusy", 6, $sd));
end
```

Finally, the last constraint is related with the technician skills required by the service requested. You can see, it has more importance than the location but less than the technician availability:

```
rule "skillMatch"
    when
        $sd : ServiceRequest($neededSkills : neededSkills, $tec : technician)
    then
        Set<Skill> tempSkills = EnumSet.copyOf($neededSkills);
        tempSkills.removeAll($tec.getSkills());
        insertLogical(new IntConstraintOccurrence("skillMatch",
             tempSkills.size() * 3, $sd));
end
```

The last rule is used to calculate the score of the current step, aggregating the weights of the *IntConstraintOccurrence* objects inserted by other rules. This rule was also assigned with a lower salience value to be only evaluated after the score rules.

Even though the use of *salience* is not the best practice, we need it to control the rule evaluation order to gain performance in the score calculation:

```
rule "hardConstraintsBroken"
salience -1 // Do the other rules first (optional, for performance)
    when
        $hardTotal : Number() from accumulate(
              IntConstraintOccurrence($weight : weight), sum($weight))
    then
        scoreCalculator.setScore(- $hardTotal.intValue());
end
```

Once the score rules are defined, we have to create the solver configuration file. It's a simple XML file that will configure the solving algorithm behavior. The currently available solver in OptiPlanner is local search, which can be configured to use Tabu search and simulated annealing acceptors.

The acceptor is used to activate a Tabu search or simulated annealing and will assign an accept-change value for each generated move. In this recipe, we are using Tabu search and we are going to configure one of the several Tabu types. The solution Tabu is one of the recommended ones because it tends to gives the best results and requires little or no tweaking.

Finally, we arrive at the *forager* section. A forager has the responsibility to gather all the accepted moves and pick the one that will be the next step and normally will be the accepted move with the highest score. Here, we can configure whether and how the forager will pick the next move early using one of the following values. Using the *NEVER* value, a move will never be picked early, but there are two more possible values:

- *NEVER*: A move will never be picked early. This is the default value.

- *FIRST_BEST_SCORE_IMPROVING*: Picks the first accepted move that improves the best score. If there is none, then it behaves exactly the same as *NEVER*.
- *FIRST_LAST_STEP_SCORE_IMPROVING*: Picks the first accepted move that improves the last step score. If there is none, then it behaves exactly the same as *NEVER*.

It is possible that the selected technician isn't the absolute best option, but it should be an effective solution to the problem. Finally, you may want to know that there are many different solutions:

- A **possible solution** is a solution that does or does not break any number of constraints. Planning problems tend to have a large number of possible solutions; however, most of them are worthless.
- A **feasible solution** does not break any hard constraints. Sometimes, there are no feasible solutions, and every feasible solution is a possible solution.
- An **optimal solution** is one with the highest score. There is always at least one optimal solution to a planning problem.

7.5 Summary

In this example we have seen Drools stream mode for complex event processing and OptiPlanner for solving complex IoT event reasoning problems. Events in Drools are immutable objects with strong time-related relationships. CEP has a great value, especially if we need to make complex decisions over a high number of events. We've seen the use of time/length sliding windows and temporal operators.

This example also discussed the Drools type declarations which can define metadata on top of the existing types or define new types. As was demonstrated, new types are useful for rule decomposition.

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