INSIDE JVM

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WHAT IS A JVM?

- JVM (Java Virtual Machine) is an abstract machine.
- It is a specification that provides runtime environment in which java bytecode can be executed.

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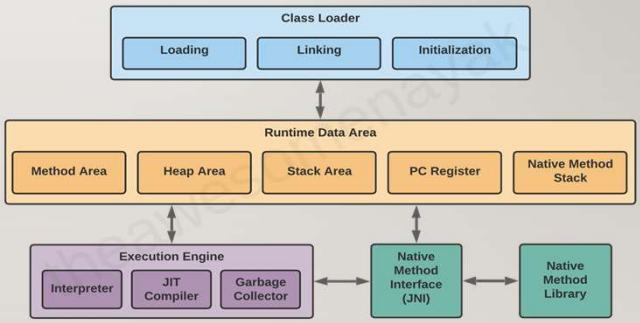
JVM ARCHITECTURE

- The JVM consists of three distinct components:

1. Class Loader
2. Runtime Memory/Data Area
3. Execution Engine



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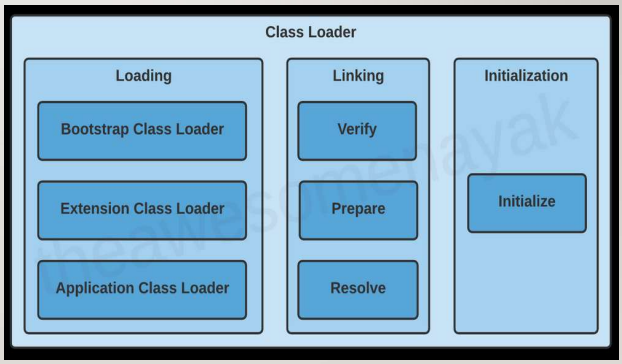
CLASS LOADER

- The class loader loads the classes into the main memory.
- There are three phases in the class loading process:
  - Loading
  - Linking
  - Initialization



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LOADING

- Loading involves taking the binary representation (bytecode) of a class or interface with a particular name, and generating the original class or interface from that.
- There are three built-in class loaders available in Java:
  - **Bootstrap Class Loader**
  - **Extension Class Loader**
  - **Application Class Loader**
- The JVM uses the **ClassLoader.loadClass()** method for loading the class into memory.

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LINKING

- Linking a class or interface involves combining the different elements and dependencies of the program together.
- Linking includes the following steps:
  - **Verification**
  - **Preparation**
  - **Resolution**

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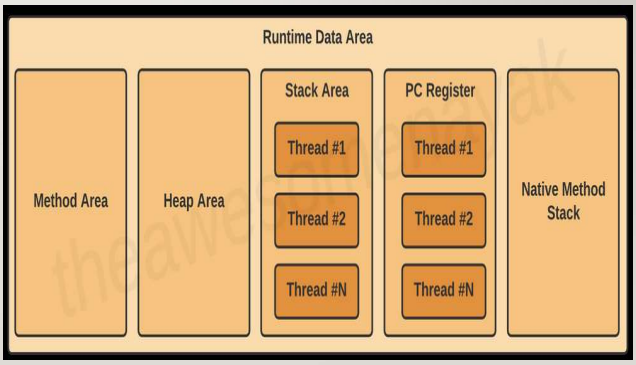
INITIALIZATION

- Initialization involves executing the initialization method of the class or interface (known as <clinit>).
- This can include calling the class's constructor, executing the static block, and assigning values to all the static variables.
- This is the final stage of class loading.

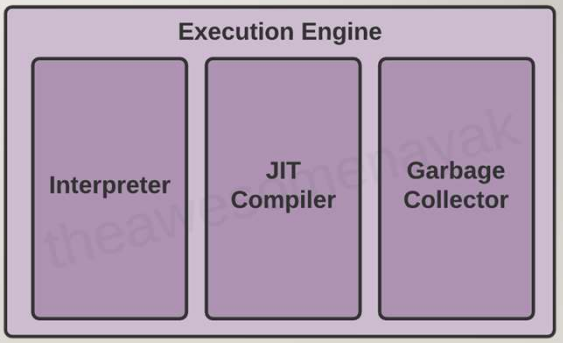
RUNTIME DATA AREA

- There are five components inside the runtime data area:
  - **Method Area**
  - **Heap Area**
  - **Stack Area**
    - **Local Variables**
    - **Operand Stack**
    - **Frame Data**
  - **Program Counter (PC) Registers**
  - **Native Method Stacks**



EXECUTION ENGINE

- The Execution Engine executs the code present in each class.
- Execution engine has 3 components:
  - **Interpreter**
  - **JIT Compiler**
  - **Garbage Collector**



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GARBAGE COLLECTOR

- The Garbage Collector (GC) collects and removes unreferenced objects from the heap area.
- It is the process of reclaiming the runtime unused memory automatically by destroying them.
- It involves two phases:
  - **Mark -** in this step, the GC identifies the unused objects in memory
  - **Sweep -** in this step, the GC removes the objects identified during the previous phase
- Compact remaining objects in memory

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DE-REFERENCING OBJECTS

- The main objective of Garbage Collection is to free heap memory by destroying the objects that don't contain a reference.
- There are various ways in which the references to an object can be released:
  - **By making a reference null**
  - **By assigning a reference to another**
  - **By using an anonymous object**

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GARBAGE COLLECTION ROOTS

- Garbage collectors work on the concept of *Garbage Collection Roots* (GC Roots) to identify live and dead objects.
- Examples of such Garbage Collection roots are:
  - Classes loaded by system class loader (not custom class loaders)
  - Live threads
  - Local variables and parameters of the currently executing methods
  - Local variables and parameters of JNI methods
  - Global JNI reference
  - Objects used as a monitor for synchronization
  - Objects held from garbage collection by JVM for its purposes

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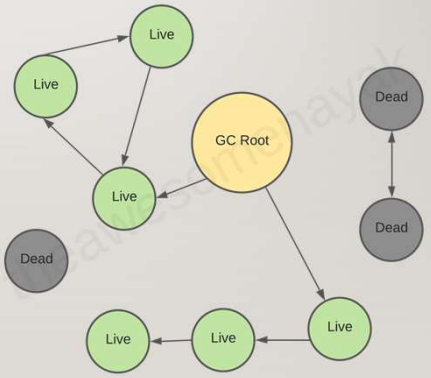
- The garbage collector traverses the whole object graph in memory, starting from those Garbage Collection Roots and following references from the roots to other objects.



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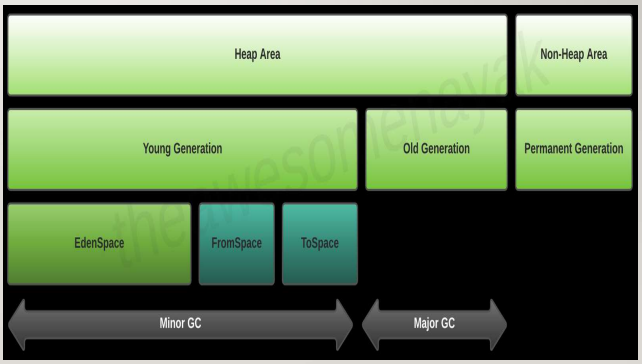
GENERATIONAL GARBAGE COLLECTION

- Java Garbage Collectors implement a *generational garbage collection strategy* that categorizes objects by age.
- **Young Generation**
  - Eden space
  - Survivor spaces (FromSpace and ToSpace)
- **Old Generation**
- **Permanent Generation**



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GARBAGE COLLECTOR TYPES

- JVM contains 3 different types of garbage collectors:
  - **Serial GC –** JVM argument => -XX:+UseSerialGC
  - **Parallel GC –** JVM argument => -XX:+UseParallelGC
  - **Garbage First (G1) GC –** JVM argument => -XX:+UseG1GC

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THREAD DUMPS

- **A thread dump is a snapshot of the state of all the threads of a Java process**.
- The state of each thread is presented with a stack trace, showing the content of a thread's stack.
- A thread dump is useful for diagnosing problems as it displays the thread's activity.
- **Thread dumps are written in plain text, so we can save their contents to a file and look at them later in a text editor**.

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JDK UTILITIES – THREAD DUMPS

- The JDK provides several utilities that can capture the thread dump of a Java application.
- **All of the utilities are located under the *bin* folder inside the JDK home directory**.
- **Jstack**
  - jstack is a command-line JDK utility we can use to capture a thread dump.
  - jstack [-F] [-l] [-m] <pid>
  - jstack 17264 > /tmp/threaddump.txt
- **Jcmd**
  - jcmd 17264 Thread.print

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HEAP AND NON-HEAP MEMORY

- **Heap memory**
  - This is the runtime data area from which the Java VM allocates memory for all class instances and arrays.
  - The heap may be of a fixed or variable size.
  - The garbage collector is an automatic memory management system that reclaims heap memory for objects.
- **Non-heap memory**
  - includes a method area shared among all threads and memory required for the internal processing or optimization for the Java VM.

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HEAP DUMPS

- **A heap dump is a snapshot of all the objects that are in memory in the JVM at a certain moment**.
- They are very useful to troubleshoot memory-leak problems and optimize memory usage in Java applications.
- **Heap dumps are usually stored in binary format hprof files.**
- We can open and analyze these files using tools like JVisualVM. Also, for Eclipse users it's very common to use MAT.

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JDK TOOLS – HEAP DUMPS

- The JDK comes with several tools to capture heap dumps in different ways.
- **All these tools are located under the *bin* folder inside the JDK home directory**.
- **jmap**
  - jmap is a tool to print statistics about memory in a running JVM.
  - jmap -dump:[live],format=b,file=<file-path> <pid>
  - jmap -dump:live,format=b,file=/tmp/dump.hprof 12587

  (we can get the pid with jps command)

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JDK TOOLS – HEAP DUMPS

- **Jcmd**
  - jcmd is a very complete tool that works by sending command requests to the JVM. We have to use it in the same machine where the Java process is running.
  - jcmd <pid> GC.heap_dump <file-path>
  - jcmd 12587 GC.heap_dump /tmp/dump.hprof
- **Capture a Heap dump automatically**
  - `java -XX:+HeapDumpOnOutOfMemoryError -XX:HeapDumpPath=<file-or-dir-path>`

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JVM OPTIONS - CONTROLLING HEAP SIZE

- Java heap size can be controlled using the below vm options
  - Use -Xmx to specify the maximum heap size
  - Use -Xms to specify the initial Java heap size
  - Use -Xss to set the Java thread stack size
  - Use –Xmn to specify initial Java heap size for Eden generation
- Java `-Xms<heap size>[unit]`
  - Here, ***unit*** denotes the unit in which the memory (indicated by ***heap size***) is to be initialized. Units can be marked as ***'g'*** for GB, ***'m'*** for MB and ***'k'*** for KB.
  - `Java -Xms2G -Xmx5G`

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JVM OPTIONS - CONTROLLING GARBAGE COLLECTION

- The following options can be used to set GC type
  - `-XX:+UseSerialGC`
  - `-XX:+UseParallelGC`
  - `-XX:+UseG1GC`

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JVM OPTIONS – OUT OF MEMORY ERROR

- Jvm parameters to dump heap memory to file
  - `-XX:+HeapDumpOnOutOfMemoryError`
  - `-XX:HeapDumpPath=./java_pid<pid>.hprof`
  - `-XX:OnOutOfMemoryError="< cmd args >;< cmd args >"`
  - `-XX:+UseGCOverheadLimit`

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VERBOSE GC

- **Verbose garbage collection logging is often required when tuning and debugging many issues**, particularly memory problems.
- In fact, some would argue that in order to strictly monitor our application health, we should always monitor the JVM's Garbage Collection performance.
- **For each GC happening, the GC log provides exact data about its results and duration.**
- **It helps optimize GC frequency and collection times by specifying the best heap sizes, other JVM options, and alternate GC algorithms.**
- `-XX:+UseSerialGC -Xms1024m -Xmx1024m -verbose:gc`

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JCONSOLE

- The JConsole graphical user interface is a monitoring tool that complies to the Java Management Extensions (JMX) specification.
- JConsole uses the extensive instrumentation of the Java Virtual Machine (Java VM) to provide information about the performance and resource consumption of applications running on the Java platform.
- The jconsole executable can be found in JDK_HOME/bin, where JDK_HOME is the directory in which the Java Development Kit (JDK) is installed
- You can use JConsole to monitor both local applications, namely those running on the same system as JConsole, as well as remote applications, namely those running on other systems

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VISUAL VM

- VisualVM provides detailed information about Java applications while they are running on the Java Virutal Machine (JVM).
- VisualVM's graphical user interface enables you to quickly and easily see information about multiple Java applications.
- VisualVM perfectly fits all the requirements of application developers, system administrators, quality engineers and end users.