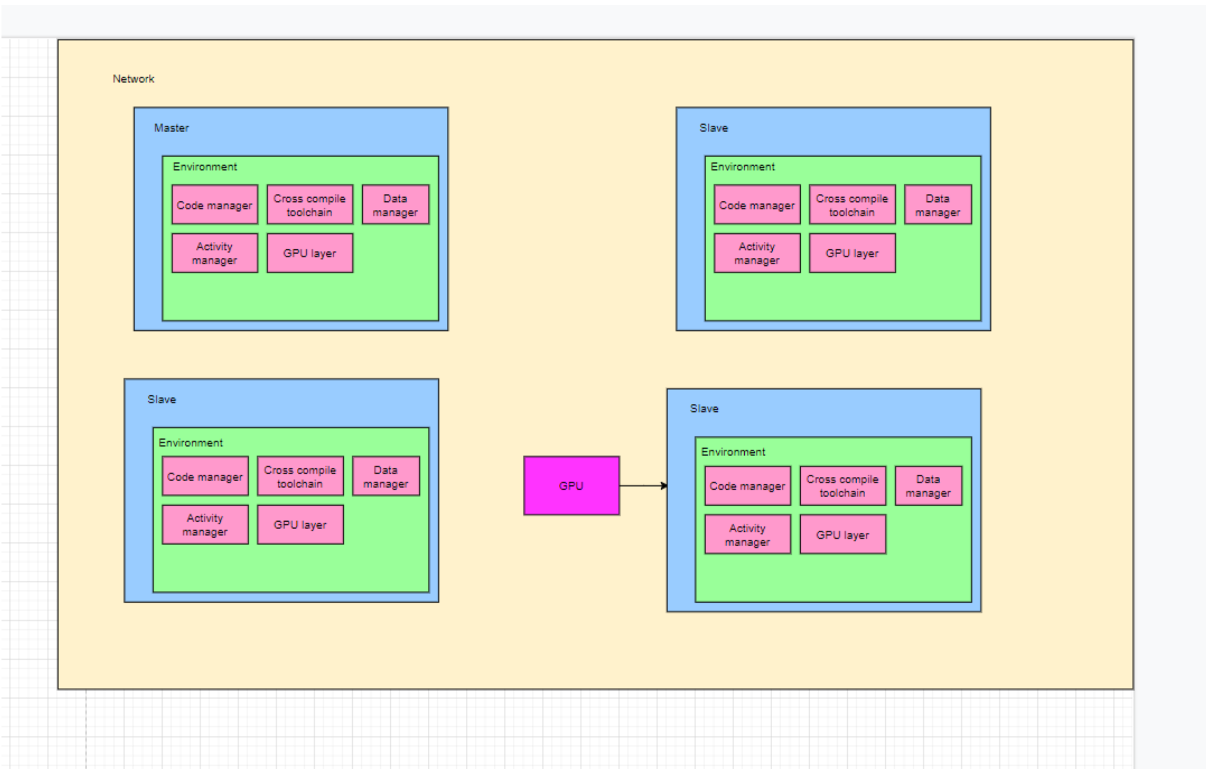
Introduction

Main concepts

Building blocks



Several components are listed in the following table

Name	**Description**	**Tasks**
Environment	Sets up environment variables and ensures that communication between components is possible as well as component startup	- Component startup - Platform capabilities checks - Environment variable setting like PATH - Component communication tools - Framework used by other components - Configuration management
Code manager	Responsible for	- Invoking toolchain

	transferring codebetween machines	specific to machine - Sending compiled code to slaves - Loading received code from masters
Data manager	Ensured proper data exchange between nodes	- Sending data from master to slave - Sending data from slave to master - Ensuring proper encoding - Encryption
Activity manager	Ensures management of running tasks and machine discovery	- Slave discovery - Connecting to master - Running tasks - Keeping track of running tasks - Function call statistics - Smart task delegation based on profiling statistics
GPU layer		- Exchanging data CPU-GPU - Patching code for GPU - GPU discovery

Every component is started by environment startup as daemon. Daemons can be controlled through daemon control tool provided by environment. Other components are structured as control scripts which use framework provided by environment to communicate to respecting daemon for that component and also daemon services which are run on environment startup.

Toolchain

Environment also provides tooling for building code for various targets. On startup environment figures out host architecture while activity manager on master machine figures out target architectures of slaves.

Configuration

Environment reads configuration at its startup. Configuration is set of shell files which are sourced by environment. Depending on hostname, different configurations can be used or specific configuration file can be passed to environment.

Adding new components

New components can be added to environment which can enable more features. This includes:

- Adding new supported target architecture for CPU
- Adding new supported GPU
- Adding new component which will be started on environment startup
- Adding new language support to Code manager
    - Function discovery
    - Compilation
    - Loading
    - Unloading
- Adding new communication protocol to Activity manager

Logging

Framework provided by environment offers functions for logging. Logging can be controlled by configuration where certain levels of logging are logged. User can configure what levels are shown on console and what are written to log file for specific component. Environment also offers tool for aggregating and merging all logs and showing them to standard output.

Component implementation

All components are implemented in C++17 standard. Here are few things which are worth noting for component implementation:

- For thread management is used std::thread
- Code manager keeps track of compiled sources and for which architecture they are compiled, ensuring not doing two tasks twice. It also keeps track of hash of code such that it compiles only when code is changed.
- Code manager has inotify attached to filesystem watching for code changes.
- Activity manager notifies code manager of all needed architectures through named pipe

- When slave structure changes, code manager is notified and recompiles code for newly added architectures
- Data manager on master is responsible for data splitting and sending each chunk to slaves. When data is received from master, master then invokes activity manager to run Task on all slaves and master included. Code managers are notified by activity managers to load code and run task with arguments provided by data managers.
- Every component, when accessing data structure shared between threads, it has to synchronize this part to other threads.
- Every component has to initialize itself using framework library provided by environment
- Every component should use framework library provided by environment to communicate to other components
- Every component has to use framework for logging.
- Code manager, when loading code and running code, it should fork itself in case task fails. Code manager should never terminate unless stopped by environment
- Environment watches if all components are still running and if one daemon terminates, it should restart it and notify other components
- Other components should recognize failure of individual components and resend data again
- Environment, when component initialized, will create named pipe where other components can send data to this component
- Environment will send message to every component when all components are running and are ready to get messages.

Data manager

Data manager is responsible for data storage, data splitting and data sending to individual nodes.

Data storage is abstraction over finite or infinite set of data which can be of several types:

- Numbers container in file
- Range specification (Range(a,b, step), Range(a, …, step) and Range(…, a, step))
- Result of executing task (ResultOf(path, param1, ….)) or ResultOf(TaskID)
- Text file where each line is separate data entry
- union data sources

- cross product of data sources
- intersection of data sources

Data manager can create these data sources and store them in its memory. Each data source, when created, is split among several slaves.

For data source creation, two things are provided to data manager:

- data source definition (see above)
- involved nodes specification (see section below)

Data manager will distribute data according to given data to all nodes through activity manager by sending message with DATA performative with these specification and activity manager will use its node specification parser to understand which nodes to distribute to.

Data manager supporrts listing of all data sources on all connections.

When invoking task, data can be provided to Task as follows:

- Give data through Loader using its loadData(DataSource) mechanism and individual loaders will have to implement this logic. This is done before running code but after loading it. It is done on slave nodes on which task is invoked and it will fetch data from respected data manager on that slave. For this purpose activity manager will support giving data sources and sending their ids to slaves when running task.

Involved nodes specification

When referencing nodes which are responsible for task in activity_manager or for data source in data manager, several node specifications can be used:

Language	Description
*	Select all nodes currently connected to master
Spec1+spec2	Select nodes satisfying spec1 OR spec2
Spec1,spec2	Select nodes satisfying spec1 AND spec2
(expression)	Group condition into brackets giving operator precedence
name=<node name>	Select node with given name
[param]=value	Select node which has its value set to given parameter
!spec1	Select nodes not satisfying spec1
%	Select master node

Language	Description

Continious integration and testing

All components are tesed on three levels:

- Unit tests
- Integration tests – for whole component
- System test – whole environment with communication with other machines

Unit tests

Unit tests are implemented for framework and for each component. For both cases, gtest framework is used.

For framrwork, tests are located inside framework/test directory while for components in components/<component_name>/test

For every case, single binary is generated in build system which runs all tests.

Integration tests

Integration tests are implemented as shell scripts in directory **test**.

They are organized into modules.

Structure of directory is shown below:

- test/
  - runAll.sh – runs all modules
  - run.sh – script which runs specific moduletest
  - <modulename>/
    - config/ - holds test specific configuration to be used
    - run.sh – this is script which is run when this test for this module is run. In this script, it can be assumed that environment is initialized with given configuration.
    - src/ - code containing CmakeLists.txt to compile specific integration test source code if needed

System tests

These tests are run by ussing several docker containers with conal image to test inter-node communication. They are contained in system_test/ directory and every test is one directory which has at least run.sh script to run the test. In this directory, there is also runAll.sh to run all the tests.

Continious integration with Jenkins

For CI/CT, Jenkins will be used. There are several gates which need to pass for every commit to master:

- Code has to be built
- CoNAL can be installed to *opt/*conal/
- All unit tests pass
- All integration tests pass

Profiling

Since only performance requirement is environment startup, measurement can be done from time environment is started until all component are ready to get messages.

Development environment

In the following list, tools are shown which will be used:

- Daemons: C++
- Framework: C++ and Boost
- Tooling from environment: C++ with developed framework
- Environment: Bash
- Controlling tools: C++ with framework
- Build system for tooling and daemons: CMake
- Container engine for development: Docker image will be created
- CI: Jenkins
- Unit tests: gtest and gmock
- Integration test: Bash
- System test: Multiple Docker containers in the same network and “empty” tool which executes and sends commands to environment

- Documentation handling: Microsoft Word

Code loading and task management model

Code manager will be made of several classes:

- LoaderManager – class which searches loader path in CoNAL to discover all loader plugins available
- Loader interface which represents individual loader plugins:
    - Every plugin is shared object file with function createInstance which returns Loader instance
    - Loader interface has the following methods to implement:
        - verify(std::vector<std::string> params, std::map<std::string, std::string> machineParams) -> bool – returns if given loader can be used to load code given in parameters
        - load(std::vector<std::string> params, std::map<std::string, std::string> machineParams) -> Base64Array – loads code and return base64 representation suitable for sending, incase program needs to be compiled, this function searches for toolchain and compiles code.
        - start(Base64Array data) – extracts the code to the given space and runs it

Task manager has Task object which has the following features

- List of pointers to Connection objects to which task is assigned
- prepare method which sends task information to each connection. Invokes specific code loader for every connection.
- Load method which will be called when code manager sends loaded data to activity manager. This method is called for each Connection pointer.
- Start method which is called when all loaders are finished. This method sends code for each connection to given host.
- State which holds current state of task object.
- Listeners which contains list of listeners to state transitions

Listener interface has only one method “onStateChange” which is called by Task object. It receives three parameters:

- Reference to task object
- Old state
- New state

For each state transition from task_assignment diagram, different listener class is implemented. When Task is created, all listeners are registered.

Description of task

Different variants of tasks depend on loader used but usually task is modeled as model-based agent with the following features:

- Run method which is invoked by loader to run task
- access to data manager to fetch data available to agent