Distributed Machine Learning Toolkit (DMTK)

Microsoft Research Asia

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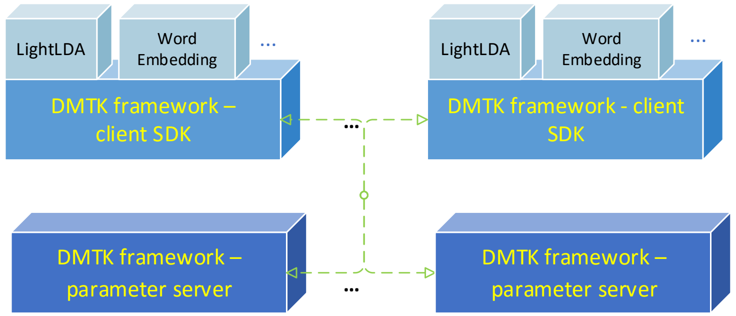
Overview

- Introduction to DMTK
- Using Binary Tools in DMTK
- Developing Your Own Algorithms on DMTK
- Resource and Support

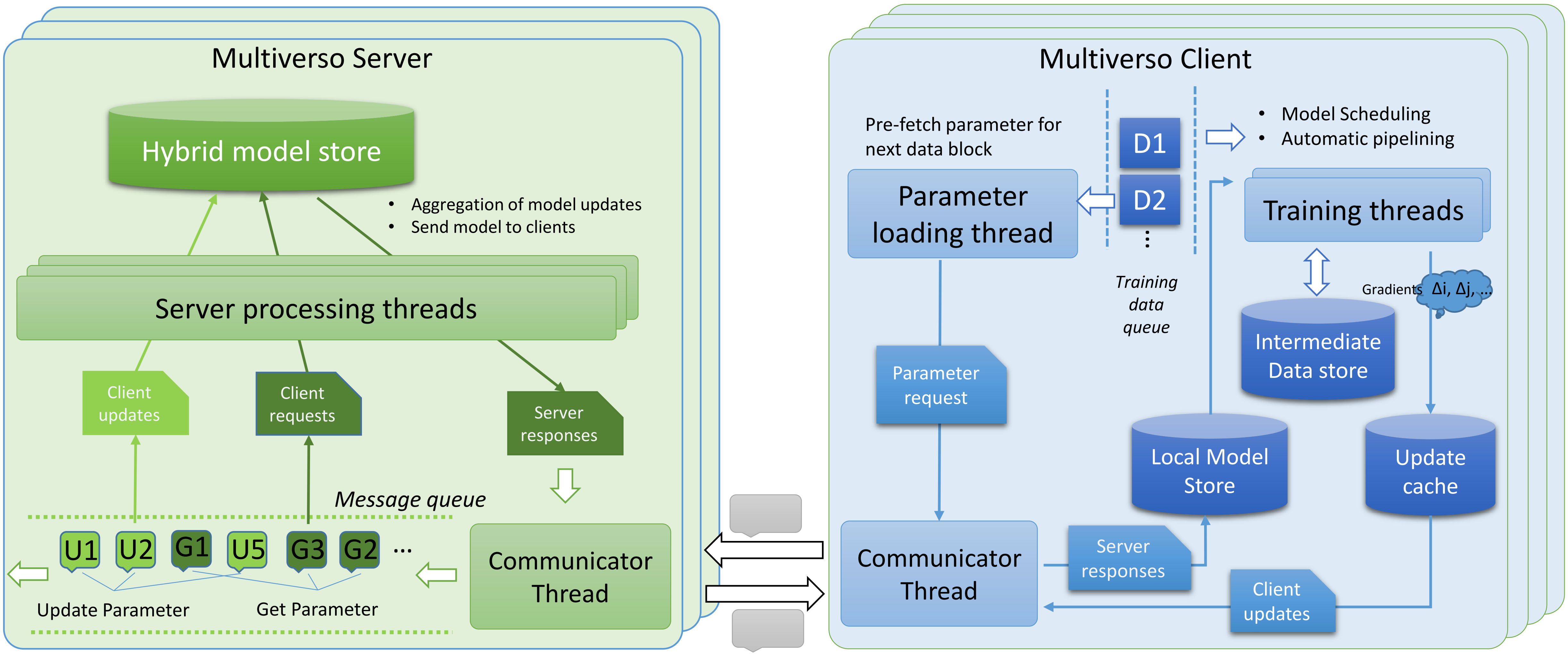
DMTK

- DMTK (current release) includes
  - Distributed machine learning framework (code name: Multiverso)
    - Parameter server + client SDK for developing distributed machine learning algorithms
  - Two distributed algorithms implemented on Multiverso
    - LightLDA
      - Distributed trainer for LightLDA[1] topic model
    - Distribute Word Embedding(DWE)
      - Distributed trainer for word2vec[2] (abbr. as DWE) and multi-sense word embedding[3] (abbr. as DMWE).



[1] Jinhui Yuan, Fei Gao, Qirong Ho, Wei Dai, Jinliang Wei, Xun Zheng, Eric Xing, Tie-Yan Liu, and Wei-Ying Ma, LightLDA: Topic Models on Modest Computer Cluster, WWW 2015.
[2] Tomas Mikolov, Kai Chen, Greg Corrado, and Jeffrey Dean. Efficient Estimation of Word Representations in Vector Space. ICLR 2013
[3] Fei Tian, Hanjun Dai, Jiang Bian, Bin Gao, Rui Zhang, Enhong Chen, and Tie-Yan Liu. A probabilistic model for learning multi-prototype word embeddings. COLING 2014.

Multiverso Framework



Software and Hardware Requirements

- Running platform - x64
  - Tested on Windows server 2012, and Ubuntu 12.04
- Developing environment and compilers
  - The codes were developed with Visual Studio 2013 on Windows; slight code conversion might be needed when using other versions of Visual Studio.
  - The codes were compiled with g++ 4.8 on Linux.
- Welcome to help us migrate DMTK to other environments

Using Binary Tools

Runining LightLDA and Distributed Word Embedding(DWE/DMWE)

Prerequisites

- Install MPI/ZMQ
  - https://github.com/Microsoft/multiverso/tree/master/windows
- Firewall exception
  - If your cluster has firewall enabled, please make sure you have firewall exception for the following network applications
    - All binaries for MPI, i.e., executables in the "bin" folder under the MPI path
    - The commands you are going to run on MPI/ZMQ, e.g., LightLDA.exe
    - Server applications (when using ZMQ as inter-process communication library)
- Make third-party dlls ready for applications
  - Mpi.dll, ZMQ-related dlls.
  - Make sure they are in the system path or in the application path

Running Multiverso

- Multiverso supports two inter-process communication modes
  - MPI:
    - The parameter server routines are bound to the worker processes running as server threads. MPI will help start all the applications.
    - Command line to start a MPI job: *mpiexec.exe –machinefile machineFile app.exe –yourAppArgs* …
  - ZMQ:
    - The parameter server is a standalone process. You need to start servers and your client applications separately. For client applications, a server endpoint file is needed, which contains the *ip:port* information of each server line by line.
    - Go to every server and start the following commands:
      - To start server: *multiverso_server.exe server_id worker_number*
      - To start a particular client task: *app.exe –server_endpoint_file server_file -yourAppArgs …*

More about MPI Jobs

- Follow the Prerequisites page to install MPI, and add firewall exceptions
- Before running the MPI job, please make sure you have started “SMPD.exe –p port_id –d” on each machine. The port_id is the port used to communicate among MPI nodes.
- Compose the machine.txt file to specify the machine names (or IPs) and node (or process) number on each machine.
- Run the following command to kickoff the distributed training on any machine within the cluster.

```
mpiexec –p port_id -machinefile machine.txt path\App.exe -arguments
```

```
MACHINE1 2
MACHINE2 4
```

- Remarks
  - Please make sure every machine has the working directory on their local disk.
  - Please make sure port_id is consistent with the value you start smpd.

In this example, machine1 and machine2 are used: 2 nodes (processes) on machine1, and 4 nodes (processes) on machine2.

Running LightLDA

- LightLDA only accepts binary input data; we have provided a tool to convert libsvm format text file to the desirable binary file.

- For more details, please refer to
  - https://github.com/Microsoft/lightlda/tree/master/example

Running DWE/DMWE

- DWE/DMWE only accepts raw text file as input. In addition, **Vocabulary file, stop words file** are also required. We have provided a tool to generate vocabulary file based on the raw text.

- For more details, please refer to
  - https://github.com/Microsoft/distributed_word_embedding/examples

Developing Your Own Algorithm

Build more new distributed machine learning algorithms based on Multiverso

Setup Development Environment

- Download

  git clone https://github.com/Microsoft/multiverso

- Build
  - On Linux
    - Run ./third_party/install.sh
    - Run make all –j4
  - On Windows
    - Install third-party libraries
      https://github.com/Microsoft/multiverso/tree/master/windows
    - Open windows/multiverso.sln, change configuration and platform as Release and x64, then build the solution.

Key Steps

- Define the main training routine
  1) Start the Multiverso environment
  2) Configure the Multiverso parameter server
  3) Define the overall training process based on user defined data block
- Implement you algorithm logic
  1) Define your data block
  2) Define parameter loader
  3) Define training logic of each data block

Start the Multiverso Environment

- Initialize the Multiverso environment.
  - pass the configuration to the environment by setting a ***Config*** object.
  - call the ***Init*** function to start Multiverso.
    - Parameters of ***Init*** function include ***trainer*** and ***parameter loader***, which define the detailed training algorithm.
  - call ***Close*** to close Multiverso.

- ***Remark***
  - More details could be found on our website
  - We also have comprehensive comments in the source codes to aid your programming

```
int main(int argc, char* argv[])
{
    // Step 1: Init Multiverso Environment
    // Set the configuration
    Config config;
    config.num_trainers = 1; config.num_servers = 1; config.max_delay = 0;

    // Trainer and Loader will be defined later
    std::vector<TrainerBase*> trainers(config.num_trainers, new Trainer());
    ParameterLoaderBase* loader = new ParameterLoader();

    Multiverso::Init(trainers, loader, config, &argc, &argv);

    // Step 2: Config the table in Parameter Server
    Multiverso::BeginConfig();

    const int kTableId = 0, kNumRows = 1, kNumCols = 10;
    // Create Table in Parameter Server
    Multiverso::AddTable(kTableId, kNumRows, kNumCols, Type::Int, Format::Dense);
    for (int k = 0; k < kNumCols; ++k)
        // Init the value in Parameter Server
        Multiverso::AddToServer<int>(kTableId, kNumRows, kNumCols, 1);

    // Finish Configuration
    Multiverso::EndConfig();

    // Step 3: Train
    const int kNumIteration = 100;
    Multiverso::BeginTrain();

    for (int i = 0; i < kNumIteration; ++i)
    {
        Multiverso::BeginClock();

        // DataBlock will be defined later
        DataBlock* data = GetDataBlock();
        Multiverso::PushDataBlock(data);

        Multiverso::EndClock();
```

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Configure Multiverso Parameter Server

- Multiverso stores parameters as ***Table***. Before training, you need to configure and initialize the server tables by adding your logic between these two methods: ***BeginConfig***, ***EndConfig***.

- *Configure tables*
  - Call ***AddTable*** to create tables in both local cache and parameter server
  - Call ***SetRow*** method to set row property, like size, format, type, etc.
- *Initialize tables*
  - Call ***AddToServer*** , if you want to initialize the server tables with non-trivial values.

```
int main(int argc, char* argv[])
{
    // Step 1: Init Multiverso Environment
    // Set the configuration
    Config config;
    config.num_trainers = 1; config.num_servers = 1; config.max_delay = 0;

    // Trainer and Loader will be defined later
    std::vector<TrainerBase*> trainers(config.num_trainers, new Trainer());
    ParameterLoaderBase* loader = new ParameterLoader();

    Multiverso::Init(trainers, loader, config, &argc, &argv);

    // Step 2: Config the table in Parameter Server
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    for (int k = 0; k < kNumCols; ++k)
        // Init the value in Parameter Server
        Multiverso::AddToServer<int>(kTableId, kNumRows, kNumCols, 1);

    // Finish Configuration
    Multiverso::EndConfig();

    // Step 3: Train
    const int kNumIteration = 100;
    Multiverso::BeginTrain();

    for (int i = 0; i < kNumIteration; ++i)
    {
        Multiverso::BeginClock();
```

Define Training Process

- The training logic should be placed between these two methods: ***BeginTrain*** and ***EndTrain***. Then Multiverso will schedule the training process based on data blocks.
- In distributed training, the concept of ***clock*** is needed, which refers to a local training period. For each clock we do a sync-up with parameter server. To define a clock, you need to call ***BeginClock*** and ***EndClock*** to tell Multiverso that the data fed are within the clock.
- In a clock period, you may feed one or more data blocks into Multiverso by calling ***PushDataBlock.***

```
    Multiverso::Init(trainers, loader, config, &argc, &argv);

    // Step 2: Config the table in Parameter Server
    Multiverso::BeginConfig();

    const int kTableId = 0, kNumRows = 1, kNumCols = 10;
    // Create Table in Parameter Server
    Multiverso::AddTable(kTableId, kNumRows, kNumCols, Type::Int, Format::Dense);
    for (int k = 0; k < kNumCols; ++k)
        // Init the value in Parameter Server
        Multiverso::AddToServer<int>(kTableId, kNumRows, kNumCols, 1);

    // Finish Configuration
    Multiverso::EndConfig();

    // Step 3: Train
    const int kNumIteration = 100;
    Multiverso::BeginTrain();

    for (int i = 0; i < kNumIteration; ++i)
    {
        Multiverso::BeginClock();

        // DataBlock will be defined later
        DataBlock* data = GetDataBlock();
        Multiverso::PushDataBlock(data);

        Multiverso::EndClock();
    }

    Multiverso::EndTrain();
    // End of Multiverso: Close the Multiverso Environment
    Multiverso::Close();
    return 0;
}
```

Define Your Data Block

- Multiverso schedules the training process based on data blocks. To define your data block, you just need to inherit the ***DataBlockBase*** class and implement your own data block.

- In ***DataBlockBase***, you might need to define the functions for
  - composing data block from input data stream (in the form of file or memory buffer).
  - getting training examples from data block.

```
class DataBlock : public DataBlockBase
{
    // Defines what's your training data
};
class Trainer : public TrainerBase
{
public:
    // Defines your training logic for a data block 'data'
    // When calling this function, you can assume that all data
    // and parameter needed is local. Parameters have been prefetched
    // from parameter server by multiverso. Then you can write your
    // training logic as same as writing a single machine program.
    void TrainIteration(DataBlockBase* data) override
    {
        DataBlock* data_block = reinterpret_cast<DataBlock*>(data);

        // The API GetRow<T> and Add<T> are member function inherited
        // from the TrainerBase

        // Access model, it is local memory access, no network happened here
        Row<int>& row = GetRow<int>(kTableId, kRowId);

        std::vector<int> updates;
        // Your training logic to produce updates
        // TODO
        // ...
        Add<int>(kTableId, kRowId, updates);
    }
};


class ParameterLoader : public ParameterLoaderBase
{
```

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Define Parameter Loader

- You need to implement parameter preparation and training for each data block separately, so that Multiverso can pipeline the process to enhance system throughput.
- ***ParameterLoader*** is used to prepare parameters needed by training. To implement your loader, you need to inherit the ***ParameterLoaderBase*** class and override the ***ParseAndRequest*** method. In the method, you need to
  - Implement logics to parse the data block and identify a set of parameters needed during the upcoming training process.
  - Use ***RequestTable***, ***RequestRow***, or ***RequestElement*** to pull these parameters from parameter servers.

```
    void TrainIteration(DataBlockBase* data) override
    {
        DataBlock* data_block = reinterpret_cast<DataBlock*>(data);

        // The API GetRow<T> and Add<T> are member function inherited
        // from the TrainerBase

        // Access model, it is local memory access, no network happened here
        Row<int>& row = GetRow<int>(kTableId, kRowId);

        std::vector<int> updates;
        // Your training logic to produce updates
        // TODO
        // ...
        Add<int>(kTableId, kRowId, updates);
    }
};
```

```
class ParameterLoader : public ParameterLoaderBase
{
public:
    // Defines which parameter you need for training this data block
    void ParseAndRequest(DataBlockBase* data) override
    {
        RequestTable(kTableId);
        RequestRow(kTableId, kRowId);
    }
};
```

Define the Training Logic

- Multiverso will create training threads based on user-defined data blocks.
- These training threads will call **Trainer** to perform the training. To implement your trainer, please inherit the ***TrainerBase*** class and override the ***TrainIteration*** method.
- In the method, you can
  - implement your training logic to process the training samples in the data block
  - Use the ***GetRow*** method to access parameters in local cache
  - Use the ***Add*** method to update the parameters.

```
class DataBlock : public DataBlockBase
{
    // Defines what's your training data
};
```

```
class Trainer : public TrainerBase
{
public:
    // Defines your training logic for a data block 'data'
    // When calling this function, you can assume that all data
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    // training logic as same as writing a single machine program.
    void TrainIteration(DataBlockBase* data) override
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        Row<int>& row = GetRow<int>(kTableId, kRowId);

        std::vector<int> updates;
        // Your training logic to produce updates
        // TODO
        // ...
        Add<int>(kTableId, kRowId, updates);
    }
};
```

```
class ParameterLoader : public ParameterLoaderBase
```

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Resources

- DMTK Website
  https://www.dmtk.io
- DMTK Source Codes
  https://github.com/Microsoft/DMTK
- DMTK Documents
  http://www.dmtk.io/document.html
- Multiverso API Documents
  http://www.dmtk.io/multiverso/annotated.html

Support

- Please send email to dmtk@microsoft.com for technical support or bug reporting.

- We will continue to enrich the tutorial to aid your development on top of DMTK; please check our website and GitHub site in a regular basis for new information.