

FINAL REPORT

DISTRIBUTED PROCESSING SYSTEM WITH MAPREDUCE MODEL ON BROWSERS AND NODE.JS

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1 Abstract

2 Motivation

MapReduce[1] provides a distributed way for processing large-scale data. In traditional MapReduce implementations, a server node dispatches data and tasks to various client nodes and collect results after mapper and reducer functions are done by clients. Both server and client need efforts to configure connection and execution environment for MapReduce programs.

In order to get many clients in a more convenient way, we introduce a new kind of MapReduce client, i.e. browsers. In the initial scheme, researchers who need more computing resources do not necessary set up lots of clients; instead, they can use a HTTP server that establishes connection with clients visit the researchers website (server). Data, mappers and reducers can therefore dispatch to those browsers and execute. To support a research, a resource provider only need to keep a browser opened and connected to the server. And in the future, we can extend the functionality more by enabling other node.js[2] applications to become clients; thus researchers who are doubt for the speed of browser computing can set up client machines with node.js and libraries we provided.

3 Project Description

This library runs a program using MapReduce programming model on the server and dispatch mapper/reducer tasks to many registered client browsers program.

To register, clients visit a site hosted by the server and accept worker permissions. Javascripts of the site will create several HTML5 workers. They will be mappers or reducers (a browser client may has mapper and reducer workers concurrently), waiting for dispatching tasks and data from the server. Upon receiving works, the workers become active, execute the map/reduce works, return results back after finishing execution repeatedly.

Different with the traditional MapReduce model, we can't communicate between browsers since the standard of communication between browsers is not popular in this time, so the intermediate result done by map workers will be report to themselves, and then shuffle these intermediate results to the reduce workers.

Also there will be an API for node.js that provides adapters connecting server-side javascripts and node.js computing environment. Eventually the server can also dispatch tasks to node.js servers, i.e. treating node.js as a powerful MapReduce computing nodes.

4 Technologies and Open Source Projects

In order to achieve our motivations, it is necessary to give a brief survey first to check how other projects implement the similar goal, and compare differences with our approach. The survey result can be categorized into two parts: *MapReduce-like implementation* and *javascript libraries and techniques*. For the first part, we try to look especially into MapReduce-like projects that is implemented in javascript.

1. Atomize.js[3]: It is aimed to provide distributed objects and atomic transaction feature between the server and all clients. The clients register to server and read/write variables with server; Atomize.js ensures that the variable is treated as "global" and identical among all clients. The descriptive sample given by authors of Atomize.js is a simple online game that uses atomic feature to manage game states. For client-server connection it uses SockJS library introduced below.
2. MapRejuice[4]: MapRejuice is a simple implementation on MapReduce algorithm. It builds a web server that delivers javascript contents and use RESTful API as entrances for receiving outputs of map and reduce functions. It uses Socket.io for client-server connection.
3. WebWorker[5]: WebWorker, a.k.a. Web Worker API, is the well-known feature that comes to new browsers with HTML5 standards. Specified by W3C, the objective of WebWorker is to provide concurrent programming in browsers; therefore heavy-loaded scripts can be executed in the worker thread and it does not block the main thread of browser, which leads to no-response feels to users. In our approach, it is natural to execute map and reduce functions on a worker thread in order to speed up performance in the browser.
4. WebSocket[6]: Similar to WebWorker, it is included in the HTML5 standard. As the name shows, WebSocket provides socket programming functionalities to browsers, which traditionally rely on HTTP protocol com-

munication. WebSocket is more suitable for modern web use cases because while HTTP protocol is stateless and disconnects after response sent/received, WebSocket can create a tunnel between the server and browsers to exchange information rapidly and simultaneously. Again it is natural for our project to use WebSocket as data exchange.

5. Socket.io[7]: Although WebSocket provides socket-connection abilities to browsers, it currently has only plain API and unable to support old browsers. Socket.io tries to solve these problems with easy-to-use interfaces that wrap WebSocket APIs and use Ajax instead of WebSocket when older browser is detected.
6. SockJS[8]: It is a wrapper to WebSocket. When SockJS detects that the browser is too old to provide WebSocket functionality, it uses other methods (e.g. Ajax) to emulate socket instead. This is very similar to Socket.io, which is more popular. They both have browser/server side implementation.

5 System Architecture

In this section we describe the overall architecture that covers main components of the system, as well as go through the execution overview and discuss those components in detail.

5.1 System Overview

The system is combined with several parts:

- (I) the master server
- (II) the client browsers

For (I) we use node.js as its basic infrastructure.

For (II), though Socket.io and SockJS can give a unified interface among WebSocket enabled/disabled browsers, only WebSocket enabled browsers are allowed to use the system. Thus, the connection for MapReduce algorithm flow between (I) and (II) is done via HTML5 WebSocket API.

5.2 Execution Overview

While designing the MapReduce model for the server-browser architecture, we compromise for some additional steps (*configuration*, *signal* and *collect*) and efforts (in *split*, *shuffle* and *reduce*) to the original model due to some constraints of our architecture.

1. *Configuration*. User sets up some properties of the execution flow, e.g. data split strategy (see below).
2. *Split*. Master server split data into multiple chunks. By how configuration varies the system either splits data as fixed size, or dynamically determines number of clients and splits data to the same number. The data is split into M chunks.

3. *Dispatch.* Master server dispatch M chunks to M clients, as well as the map functions and reduce functions.
4. *Map.* The map functions take individual chunk as input, and output a set of key-value data corresponding to the chunk. Since we are using javascript the key-value data can be easily represented as a javascript object or a JSON.
5. *Shuffle.* Clients return the map results via WebSocket, and master server immediately send it to different clients by sending different key-value data to client reducer that corresponds to the key.
6. *Reduce.* Upon receiving key-value data, clients run reduce function to summing up values of the key. The data does not come at the same time so the reducer will wait for a signal referring to the end of execution.
7. *Signal.* When master receives and re-dispatches all data from every map functions, it sends END signal to all reducer clients, telling them there is no further inputs and thus reducers can terminate the process.
8. *Collect.* After reduce function is terminated, the client sends the final key-value result back to master server, which collects them and writes to the final output.

5.3 Part I: Master Server

The master server does two major works: (1) provide web content delivered to browsers, and (2) control the whole MapReduce algorithm process. We discuss them separately.

1. Web Content Delivering

The node.js server creates a HTTP server object and listens for HTTP GET requests. Upon receiving requests, the HTTP server object sends web content back via HTTP response.

The web content contains the following parts:

- HTML content: a webpage that allows user to register to server.
- Browser-side javascript program: the main component that executes MapReduce related works.
- Other assets files.

Details of the HTML content and browser-side javascript program will be discussed in Part II.

2. MapReduce Algorithm Process Control

The server begins the algorithm by firstly dispatches split data, map function and reduce function to registered clients.

In theory after all data are sent, the dispatch process is done and the server starts the shuffle process; but since node.js has a non-blocking I/O characteristic, the server runs the shuffle process in a callback which is called when map function returns the results.

For the shuffle process, the server first marks the returning client as *MAPEND* state; second, for each key-value data from mapper, it uses bucketing algorithms (described below) to decide which reducer should the key go. Finally it dispatches the key-value data to that reducer.

Upon all the clients are marked as *MAPEND*, the server knows that all initial data are mapped to key-value data, so it sends *END* signal to every reducer.

Finally, a callback awaits: when the reducer returns key-value data back, the server calls the collect process that writes the data to user-defined output location e.g. database or static files.

5.4 Part II: Browser Clients

After receiving web content from the server (or, with another word, the user visits the website hosted on the server) the user can register to the server to wait for coming tasks.

The register action builds WebSocket connection between browser and server, and the server will add the browser to one of its available client; the action will also create a WebWorker object (a.k.a. worker thread for below) that is initially pending.

When the browser receives the split data, map function and reduce function, it starts to execute mapper function on the worker thread, split data as the input.

After the mapper terminates it produces an array containing many key-value objects. The worker thread uploads the array via WebSocket.

When the upload process is done, it starts to execute the reduce function by wrapping a callback over it: only when a key-value data is sent from server will the callback be called and the reducer be executed, key-value data as the input.

When the browser receives the *END* signal instead of data from the server, the worker thread should terminate the callback wrapper and starts to upload the final result.

6 Summary

References

- [1] Dean, Jeffrey & Ghemawat, Sanjay *MapReduce: Simplified Data Processing on Large Clusters*, 2004
- [2] <http://nodejs.org>
- [3] <http://atomizejs.github.io>
- [4] <https://github.com/ryanmcgrath/maprejuice>
- [5] <http://www.w3.org/TR/workers/>
- [6] <http://www.w3.org/TR/websockets/>
- [7] <http://socket.io>

[8] <http://sockjs.org>

[9] <http://code.google.com/p/v8/>

[10] https://developer.mozilla.org/en/Rhino_Shell