KINC v0.1 Specification

Knowledge Independent Network Construction

Joshua Burns*, Stephen Ficklin*

December 11, 2015

*Dept. of Horticulture, Washington State University

Contents

1 Introduction

KINC is designed for use in construction of biological networks, specifically, gene co-expression networks.

KINC is divided into three major classes; Console, Data, and Analytic. The Console class is responsible for controlling the program and presenting the user input and output interface with data or analytic objects. The abstract Data class is an interface that is used to implement a data object which is responsible for storing certain types of biological data. The abstract Analytic class is an interface that can be used to implement an analytic object which is responsible for taking data object inputs and creating new data object from them using statistical methods.

2 Main Program

The main program consists of a console management class which acts as the program's controller and two abstract classes that create a common interface to the program. Any implementation data or analytic object must inherit and follow this interface.

2.1 Console

The Console class has a single instance within the main program and is designed to be given control through its run() function. This class creates a terminal console for the user, creates and manages all Data objects, and handles all Analytic execution.

This class also interfaces with the plugin object factory functions that generate new data or analytic interface object based off their unique names. These functions are implemented in a common source file which requires editing and recompiling whenever a new plugin is added to the program.

The KINC program upon execution presents the user with a console. Figure 1 shows the basic commands this console will support.

Command	Description
history	Shows the history of a given data file.
load	Loads a new data file with the given type and name.
export	Exports a given data file to an ASCII export file.
query	Query a given data file for information.
merge	Merge two or more data files into one, if possible.
list	List all loaded data files.
quit	Quit the program.
gpu	GPU commands.

Figure 1: Basic Console Commands

The history command is handles by this class and prints the provanence of the given data file that is loaded.

The load command is partially handled by this class. This command has two or three arguments. The first argument is always the data object type to be loaded. The next argument is the binary file of the data object. The third optional argument is a human readable text file that will be used as data to import into the data object if it is newer than the binary file.

The export command is handled by a data object. The first argument is the name of the data object to export. The second argument is the file name that it will be exported to as human readable text. Any other arguments are optional and passed to the data object referenced.

The query command is handled by a data object. The first argument is the name of the data object to query. All other arguments are optional and passed along to the data object referenced.

The merge command is handled by the new data object that merges two or more data objects into a new data object. All arguments before the last argument are data objects to be merged into this new data object. The last argument is the name of the new data object that will contain the merged data. All input data types must also be of the same type. The new data object is responsible for implementing the merging of data or do nothing and return a fail if not appropriate.

The list command is handled by this class and prints out a list of all currently loaded data objects.

The quit command will exit the KINC program.

The gpu command has a list of subcommands for querying and setting up any GPGPU device to be used with analytic objects. Figure 2 shows the subcommands pertaining to GPGPU setup through OpenCL.

Command	Description
list	List all availbale OpenCL compatible devices.
set	Set a specific OpenCL device to be used for accelerated computation.
clear	Clear any previously set OpenCL device.

Figure 2: GPU Console Subcommands

The gpu list command will give a complete list of all available OpenCL devices along with their address. An address is two numbers seperated by a colon.

The gpu set command will set the program's analytics to use a specific OpenCL device given by its address.

The gpu clear command will clear any set OpenCL device the program would use with analytics.

Any other command will be treated as the name of an analytic object to load and execute. All arguments of an analytic command will be passed to the analytic. If no analytic is found with the given name nothing is done.

Figure 3 shows the public functions this class implements.

```
Console();
void run(int,char*[]);
bool add(Data*,std::string&);
bool del(std::string&);
Data* find(std::string&);
Data* new_data(std::string&);
Analytic* new_analytic(std::string&);
```

Figure 3: Functions for Console Class

The run(...) function is called by main() and maintains control until an exit command. It provides a console for the user or executes a script, depending on the command line arguments supplied. Once the user exits the console or the script has finished executing this function returns back to main() for final program closure.

The add(...) function adds a new Data object to the list of available Data objects within the console with the name string supplied. The name must be unique from all other loaded Data objects.

The del(...) function removes the Data object from t he list with the name string specified if it exists. If it exists and it was removed it returns TRUE else it returns FALSE.

The find(...) function finds a loaded Data object with the given name. If no object is found with that name then NULL is returned, else a pointer to the found object is returned.

The new_data(...) function creates a new data object of the type specified in the supplied string. If the string is not a valid data type then NULL is returned, else a pointer to the new data object is returned.

The new_analytic(...) creates a new analytic object of the type specified in the supplied string. If the string is not a valid analytic type then NULL is returned, else a pointer to the new analytic object is returned.

The new_data(...) and new_analytic(...) functions are designed to be plugin object factories which return data and analytic objects with the type given to them as a string. These two functions along with the list of all available plugins containing their unique string names and unique number identifiers are all contained

in the same source and header file. These two files will represent where new static plugins that implement either a data or analytic interface can be added.

2.1.1 ConsoleStream

The ConsoleStream class is a common output interface to be used by all data and analytic objects for providing output to the user. This class is responsible for receiving output from objects and directing it to the user interface.

Figure 4 shows the public functions this class implements. The constructor takes a single argument which tells an instance of its output is general, warning, or error output. An enumerated list will be defined in the class for each possible output.

```
ConsoleStream(int);
void print(short);
void print(unsigned short);
void print(int);
void print(unsigned int);
void print(long);
void print(unsigned long);
void print(float);
void print(double);
void print(const char*);
void print(const std::string&);
Console& operator<<(short);
Console& operator<<(unsigned short);
Console& operator<<(int);
Console& operator<<(unsigned int);
Console& operator<<(long);
Console& operator<<(unsigned long);
Console& operator<<(float);
Console& operator<<(double);
Console& operator<<(const char*);
Console& operator<<(const std::string&);
void flush();
```

Figure 4: Functions for ConsoleStream Class

The print functions takes the given output variable and prints it to its objects output type. The overloaded stream operators do the same thing.

The flush function will flush any output given to the stream and write it to the user interface.

This class will not be instantiated by any data object. There will be three objects of this class as public variables of the Console class. Figure 5 shows the three public objects of this class the Console class will possess and what they are.

Object	Description
out	Standard output used for normal notifications.
warn	Output used for warning messages.
err	Output used for error messages.

Figure 5: ConsoleStream Objects for Console Class

2.2 Data

The abstract Data class creates a common data object interface to the console program and provides binary file input/output for any data class implementing it. This class is responsible for implementing the basic file input and output operations, reading the header of binary files and its history information, and specifying a common interface with the console program.

Additional functions should be added to any implementations of this interface class manipulating the specific type of data.

Figure 6 shows the public functions this class defines. Most of these functions are pure virtual functions that any class inheriting this class are required to implement. The constructor takes a single argument which is the binary file location where the data for an object is stored.

```
Data();
void __history();
virtual uint32_t type() = 0;
virtual bool __load(std::string&) = 0;
virtual bool __load(std::string&,std::string&) = 0;
virtual bool __export(std::string&,std::vector<std::string>&) = 0;
virtual void __query(std::vector<std::string>&) = 0;
virtual bool __merge(std::vector<std::string>&) = 0;
virtual bool flush() = 0;
```

Figure 6: Functions for Data Class

The __history() function prints the entire history of its object to the console stream.

The virtual type() function must return the unique identier of the type of data this object represents. The list of unique identifiers are stored in a common header file.

The virtual __load(...) function is called when a load console command is issued on a new data object. The first argument is the file name of the binary file to load. The optional second argument is the location of a human readable file to import if it is newer than the binary file. The data object will overwrite any current data in the binary file if it imports new data from the human readable file provided by the second optinoal argument. This function is responsible for loading data from a human readable ASCII file and encoding it into its binary format in a new file of the same name. This function returns TRUE if the command was successful else it returns FALSE.

The virtual __export(...) function is called when a export console command is issued on a given data object. The first argument is the location of the output file where the human readable format will be written to. The second argument is the list of remaining optional arguments. This function is responsible for exporting its internal data stored in binary format and decoding it into a human readable file. This function returns TRUE if the command was successful else it returns FALSE.

The virtual __query(...) function is called when a query console command is issued on a given data object. The single argument is the list of optional arguments. This function is responsible for retreiving information from data this object holds using command line arguments given.

The virtual __merge(...) function is called when a merge console command is issued on a given data object. The single argument is the list of data object names that will be merged into this new data object. This function is responsible for merging two or more seperate data objects of the same type into a new single data object. The data object this command is called on is the new data object that will merge all data from all input data objects. This function is not required to merge the given data objects if not appropriate. This function returns TRUE if the command was successful else it returns FALSE if nothing was merged for any reason.

The __load(...), __export(...), __merge(...), and flush() functions will not return control to the caller of the function until all write operations to the binary file the data object represents have completed.

Figure 7 shows the protected functions this class implements that a class inheriting this abstract class can use for file input and output of its binary data. These functions are designed to hide the raw file from an implemenation class so it is impossible to overwrite the header section of the file.

```
bool fopen(const std::string&);
uint64_t fsize();
bool fgrow(uint64_t);
void fseek(uint64_t);
template<class T> bool fread(T*,uint64_t);
template<class T> bool fwrite(T*,uint64_t);
```

Figure 7: Protected Functions for Data Class

The fopen(...) function opens the binary file given to this data object. It returns TRUE if the file was successfully opened or FALSE if it failed.

The fsize() function returns the total size of the binary file in bytes. This does not include the header information that is hidden from any implementation class.

The fgrow() function will increase the size of the binary file by the number of bytes given. If this was successful it returns TRUE else if it could not grow the size of the file it returns FALSE.

The fseek() function will move the file position's indent to the number given in bytes. This number must be within range of the total size of the binary file.

The fread(...) function reads the number of elements given and writes them to the pointer of that element type given, starting at the current file position and incrementing by the number of bytes read. The new file position cannot exceed the total size of the file.

The fwrite(...) function overwrites the number of elements given from the given pointer to the binary file, starting at the current file position and incrementing by the number of bytes overwritten. The new file position cannot exceed the total size of the file.

This abstract class is responsible for reading in the header information of any data file since it is generic to all data files. This section of the binary file is hidden from any implementation class.

Figure 8 shows the binary format for the beginning of a data file.

Name	Value	Description	Type
header	KINC	Special header tag specifying this is a KINC binary data file.	char[4]
type		Number that defines Data type for a file.	uint32_t
historySize		Total size of all history items in bytes.	uint32_t
history		Array of history items.	byte[historySize]

Figure 8: Binary File Format of Header

The header field is a special tag that specifies this is a KINC data file. The type field represents the specific type of data this file represents. The historySize field represents the total size of all history data in bytes.

Figure 9 shows the format for a single history item within the history buffer. History items are nested inside one another, the highest history element being the history of the current file, and all subhistories being the history for all input files.

Name	Description	Type
elemSize	The total size of this history item and all subhistory items it bytes.	uint64_t
fileLen	Length of file name string in bytes.	uint16_t
objectLen	Length of object name string in bytes.	uint16_t
commandLen	Length of command string in bytes.	uint16_t
date	Linux time-stamp of when file was last modified.	uint64_t
subHistoryAmt	Number of input history items.	uint16_t
subHistorySize	Size of all nested subhistory data in bytes.	uint32_t
file	File name string.	char[fileLen]
object	Name of object that built file.	char[objectLen]
command	Command line used in console to construct data file.	command[commandLen]
subHistory	Array of input history items.	byte[subHistorySize]

Figure 9: Binary File Format of Individual History Item

The elemSize field represents the total size of this history item, including all subhistory items nested within it.

The file, object, and command fields represent the name of the files, the object that created the data, and the specific KINC console command that invoked the creation of the file, respectively. The fileLen, objectLen, and commandLen give the length of the respective character strings.

The date field represents the date when this data file was last modified.

The subHistoryAmt field gives the total number of subhistory items for this history item. This does not include any input history nested within those history items. The subHistorySize represents the total size of all nested history items in bytes, respectively. The subHistory field contains the list of all nested subhistory items contained within this history item.

2.3 Analytic

The abstract Analytic class creates a common analytic interface to the console program. This class is almost a pure virtual class and accepts a pointer to an OpenCL context in its constructor, that is provided from the console.

Figure 10 shows the constructor and virtual functions that an implemenation of this class must define. The constructor takes a pointer to an OpenCL context that can be used for accelerated computation of the data, but it is not required and can be given NULL. An implementation of this class is required to provide a means to compute its data with or without an OpenCL device.

```
Analytic(cl::Context*);
virtual uint32_t type() = 0;
virtual bool execute(std::vector<std::string>&) = 0;
```

Figure 10: Functions for Analytic Class

The virtual type() function must return the unique identier of the type of analytic this object represents. The list of unique identifiers are stored in a common header file.

The virtual execute(...) function is called for this analytic to perform the computation it is designed to implement. The list of arguments given are provided by the user on the console. This command must be blocking until all file input/output has completed.

Typically this class takes input from one or more data files and creates a new data file as a result. This class is responsible for interacting with these data objects and creating a new data object if one is needed. This class must know all pertinent functions for all data types that it reads and writes.

2.4 Exceptions

Exception classes are defined for data and analytic objects. Any class implementing a data or analytic type must use their respective exception classes when throwing any exception. If a data or analytic object throws an exception the console will catch it. If the exception caught is from a data object the console will remove if from the list of loaded data objects. In either case the console will report an error to the user about the object throwing an exception.

Figure 11 shows the public functions the base exception class implements. The constructor is given 3 arguments. These arguments are the name of the file where the exception occured, the line number where it occured, and a textual description of the type of exception, respectively.

```
Exception(const char*,int,const char*);
const char* file();
int line();
const char* what();
```

Figure 11: Functions for Exception Class

The file() function returns the name of the file where the exception was thrown. The line() function returns the line in the source code where the exception was thrown. The what() function returns the specific type of exception that was thrown.

2.4.1 DataException

Inherits from Exception Class.

The DataException class must be used for all data classes when reporting errors.

Figure 12 shows the public functions this class implements. The constructor is given 4 arguments. These arguments are the name of the file where the exception occured, the line number where it occured, a pointer to the data object that threw it, and a textual description of the type of exception, respectively.

```
DataException(const char*,int,Data*,const char*);
Data* who();
```

Figure 12: Functions for DataException Class

The who() function returns a pointer to the data object and threw an exception.

2.4.2 AnalyticException

Inherits from Exception Class.

The AnalyticException class must be used for all data classes when reporting errors.

Figure 13 shows the public functions this class implements. The constructor is given 4 arguments. These arguments are the name of the file where the exception occured, the line number where it occured, a pointer to the analytic object that threw it, and a textual description of the type of exception, respectively.

```
AnalyticException(const char*,int,Analytic*,const char*);
Analytic* who();
```

Figure 13: Functions for AnalyticException Class

The who() function returns a pointer to the analytic object and threw an exception.

A Data Classes

A.1 Expression

The Expression class is responsible for manging gene expression-level data.

A.1.1 Properties

Do we need any properties?

I don't think we need properties. I am also unsure how to implement them in C++. My thought is all interactions between the classes will be defined in the Abstract Classes section using virtual functions?

A.1.2 Constructor

Data(int argc, char *argv[])

We need to design how the functions of the class will receive arguments. will we have a constructor that receives, parses and responds to errors for all functions? Or should each function be responsible for checking it's own arguments. I know we can't do that in the abstract class, but we need to accomdate the behavior we settle on in our design so plugins are consistent.

I almost completely agree. These functions and interactions will all be defined in the abstract classes section if that is OK? It is standard C++ to define everything you are talking about in the abstract interface class with virtual functions. It is usually a good idea to have a default constructor only for implemenation classes, and have any additional configuation added into additional virtual functions that any implementation must handle.

A.1.3 Virtual Functions

The following functions should be implemented by any plugin that creates classes that inherits the Data class.

virtual void import() = 0

This function reads a tab-delimited file. Each line of this file represents the gene expression levels of a single gene, transcript or probeset. Each tab-separated value in a single line indicates the gene expression level for each sample. The expression level of a samples must be in the same order for every line. The first line of the file may contain a tab-delimited list of sample names, and a file may contain as many samples and genes as desired.

A.1.4 File Structure

Figure 14 shows the binary format of expression data and how it is stored on file. geneAmt and sampleAmt give the total number of genes and samples in the data, respectively. geneNames is the list of all gene names as a string who's length and partitioning is defined by geneNameLen and geneNameSize. sampleNames is the list of all sample names as a string who's length and partitioning is defined by sampleNameLen and sampleNameSize. Lastly, samples is 2 dimensional matrix of all samples for each gene, where the matrix is sorted by gene major order.

Name	Description	Type
geneAmt	Total number of genes.	uint32_t
sampleAmt	Number of samples per gene.	uint32_t
geneNameLen	Length of each string identifying genes.	uint16_t
geneNameSize	Total size of gene name list in bytes.	uint64_t
sampleNameLen	Length of each string identifying samples.	uint16_t
sampleNameSize	Total size of sample name list in bytes.	uint64_t
geneNames	List of gene string identifiers.	char[geneNameSize]
sampleNames	List of sample string identifiers.	char[sampleNameSize]
sampleTotal	Total number of samples for all genes.	uint64_t
samples	List of all samples per gene.	float[sampleTotal]

Figure 14: Binary File Format of Expression Data

A.2 Correlation

This is responsible for storing correlation data between genes.

The following describes the format of the KINC correlation file. All multi-byte numbers are little-endian, regardless of the machine endianness.

I like this type of table for describing the file format. I borrowed it from the BAM file specification

So do I! I was actually going to convert these defintions to a tabular format after your first review. :)

Figure 15 shows the binary format of correlation data and how it is stored on file. geneAmt, sampleAmt, and corrAmt give the number of genes, number of samples per gene, and number of correlations per gene, respectively. geneNames is the list of all gene names that are correlated who's length and partitioning is defined by geneNameLen and geneNameSize. sampleNames is the list of all sample names used for correlation between genes who's length and partitioning is defiend by sampleNameLen and sampleNameSize. corrTypes is the list of all correlation types listed for all gene pairs who's length and partitioning is defined by corrTypeLen and corrTypeSize. Lastly, correlations is a special diagonal matrix where all correlations for gene pairs are stored using gene major order.

Name	Description	Type
geneAmt	Total number of genes.	uint32_t
sampleAmt	Number of samples per gene.	uint32_t
corrAmt	Number of correlations per gene relationship.	uint8_t
geneNameLen	Length of each string identifying genes.	uint16_t
geneNameSize	Total size of gene name list in bytes.	uint64_t
sampleNameLen	Length of each string identifying samples.	uint16_t
sampleNameSize	Total size of sample name list in bytes.	uint64_t
corrTypeLen	Length of each string identifying correlation type.	uint16_t
corrTypeSize	Total size of correlation type list in bytes.	uint16_t
geneNames	List of gene string identifiers.	char[geneNameSize]
sampleNames	List of sample string identifiers.	char[sampleNameSize]
corrTypes	List of correlation type strings.	char[corrTypeSize]
corrTotal	Total number of correlations for all gene relationships.	uint64_t
correlations	Diagonal matrix list of all gene correlations for all relationships.	float[corrTotal]

Figure 15: Binary File Format of Correlation Data

A.3 Network

This is responsible for storing network data between genes.

Figure 16 shows the binary format of network data and how it is stored on file. geneAmt give the number of genes in the network. geneNames is the list of all gene names that are correlated who's length and partitioning is defined by geneNameLen and geneNameSize. Lastly, network is a special diagonal matrix where all network edges for gene pairs are stored using gene major order.

Name	Description	Type
geneAmt	Total number of genes.	uint32_t
geneNameLen	Length of each string identifying genes.	uint16_t
geneNameSize	Total size of gene name list in bytes.	uint64_t
geneNames	List of gene string identifiers.	char[geneNameSize]
netTotal	Total number of edges, true or false, in network data.	uint64_t
network	Diagonal matrix list of all possible edges in gene network.	bool[netTotal]

Figure 16: Binary File Format of Network Data

A.4 Annotation

This is responsible for storing additional information for genes.

Figure 17 shows the binary format of annotation data and how it is stored on file. geneAmt and annotAmt give the number of genes and the number of annotations, respectively. geneNames is the list of all gene names who's length and partitioning is defined by geneNameLen and geneNameSize.annotNames is the list of all annotation names who's length and partitioning is defined by annotNameLen and annotNameSize. annotValSize is a list of all string lengths for each annotation value per each gene. Lastly, annotations is a 2 dimensional matrix that lists all annotations for all genes using gene major order.

Name	Description	Type
geneAmt	Total number of genes.	uint32_t
annotAmt	Total number of annotations per gene.	uint32_t
geneNameLen	Length of each string identifying genes.	uint16_t
geneNameSize	Total size of gene name list in bytes.	uint64_t
annotNameLen	Length of each string identifying the name of a annotation.	uint16_t
annotNameSize	Total size of annotation name list in bytes.	uint64_t
annotNames	List of annotation string identifiers.	char[annotNameSize]
geneNames	List of gene string identifiers.	char[geneNameSize]
annotValLens	List of numbers that identify the length of each value string for each annotation.	uint16_t[annotAmt]
annotValSize	Total size of all annotation values.	uint64_t
annotations	List of all annotations per gene.	char[annotValSize]

Figure 17: Binary File Format of Annotation Data

B Analytic Classes

B.1 Pearson

This takes an Expression BioData object and produces a Correlation BioData object. It uses the Pearson correlation statistical method for giving correlation values.

B.2 Spearman

This takes an Expression BioData object and produces a Correlation BioData object. It uses the Spearman correlation statistical method for giving correlation values.