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GSFRS: Giant Signal File Random Sampler

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Abstract— In the modern world, it is hard to imagine a day without some form of interaction with digital data. Real world data originating from signal generating transducers or communication channels are often recorded as streams of data samples separated by time stamps, sample counters or simply data record delimiter e.g. *newline* ($\backslash n$), comma (,) etc. Sampling is the basis of statistical estimation from any data source containing signal records. The process of random sampling has been in practice since time immemorial. However, rapid scale of data generation processes working in tandem with of computing infrastructures, the volume of data is getting quite unmanageably large in nearly every discipline of science. On the other hand, mere volume of data is of no consequence if we can't extract effective intelligence out of it on an "on demand" basis. Of particular interest is the case where data is stored in a file as a record separated by *newline* (or any other delimiter) character. When the number of records in the file is greater than a threshold, random sampling is a formidable task. It is nearly impossible to pragmatically load the entire file in the computer memory or even if theoretically possible, the time it takes to load the data in its entirety from natural data sources can be overwhelmingly long or often unnecessary! We can strategically bypass these problems by carefully designing a data interface tool such that any part of a given file can be instantly accessed for random sampling or other kinds of processing tasks by loading only the necessary parts of the data. With this goal, we created a novel, portable and highly efficient rapid data access tool named GSFRS: Giant Signal File Random Sampler, written in modern C++ language to enable near *real-time* access to any part of an arbitrarily large sized data file that is almost independent of the file size for all practical scenarios. Also, *big-data* processing would become relatively commonplace and cost effective even in commodity hardwares once the indices are made available through its indexing protocol. This capability would potentially revolutionize the way we gather intelligence from files containing large samples. Adaptation of *GSFRS* at the source level of various data generators, processing times and energy footprints of various computations can be dramatically reduced.

Index Terms—Big data, Random sampling, Data parsing, File handling, Data indexing, Map reduce, Signal processing, C++, CPP

1 INTRODUCTION

STATISTICAL estimation of the nature of measured digital signal is at the heart of signal processing tasks associated with large data sets. Behavior of large-scale systems are understood primarily through strategic random sampling techniques [1], [2], [3]. The entire machinery around widely

popular Monte-Carlo (MC) methods [4], [5], [6], [7], [8] hinges on the foundation of random sampling of data. MC is a relatively simple task for small data sets. However, with the stupendous growth in size of data sources, such a task is almost formidable because of the lack of *random access* to various parts of data. As per current standards, the only non-trivial way to read a large data file is by first opening the *file-stream*¹ followed by reading sequentially in a byte by byte fashion. Even with moderate file sizes, important but expensive computations like *autocorrelation* (ACF) [9], [10], [10], [11] or *mean-square-displacement* (MSD) [7], [12], [13] functions with multiple *time-lags* ($\tau_{k \in 1, 2, \dots, n}$) would practically be impossible without having random access to every record of a large data file. Because of the above reasons, we almost never observe calculations involving *autocorrelation* with large τ values in the published literature despite ACF, MSD being very important measures for time series analysis. To evaluate expensive computations like the above function at multiple discrete time lags (τ_k), we have to re-read the file many times corresponding to each τ_k ! Also, as microprocessor architectures become increasingly multi-core in nature [14], [15], [16], optimal utilization of multiple cores and available thread resources are impossible to achieve without fundamentally re-engineering the problem of asynchronous random access using modern *multi-threaded* architecture [17], [18]. Often, in many realistic scenarios, data records are stored in an *ASCII* or binary file with each line containing a sample of the data as a time stamp or serial number record. Some common examples are, high-density *EEG* data, system logs of digital events, data from financial markets etc. Even though, modern computers are enormously efficient in reading and writing small data segments from storage medium like hard drives, however, due to high quality and high-speed nature of modern real world data generation processes, the size of the data sets are also exponentially growing. So this creates a significant burden in obtaining statistical estimates of these data samples. Traditionally, large databases [19], [20], [21], [22] are utilized to get instant access to various parts of stored data. The rapid rise of custom, niche databases [23], [24] to address problem specific targeted access to large datasets is testament to the importance and need of having capabilities around customizable database technologies. A lot of *big-data* driven discoveries are enabled by these modern database technologies [25], [26]. However, in research, desktop prototype development, remote processing environments, databases

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1. https://en.cppreference.com/w/cpp/io/basic_fstream

beyond few *giga-bytes* is often a significantly resource consuming (e.g. infrastructure cost, energy, high speed internet) undertaking. Mobile and remote systems that operate on battery power, constant supply of energy is needed to manage the database infrastructure on the host machine. Even in desktop computing scenarios, often all the processing power of the multi-core processors are not optimally utilized. In order to address these issues, we developed a random data access tool capable sampling data from an arbitrarily large source data file at near clock speed of the host device without ever having to load the entire file in the memory. This tool is highly flexible, with low energy footprint and high portability. Theoretically speaking, *GSFRS* would work up to approximately 18 *exa-bytes* of storage space for 64 bit operating system architectures. Parallel computations on various parts of the data from independent processes would be a very natural practice as the need to perform serial reading from the start of the file would be completely unnecessary.

2 METHOD

2.1 Assumptions, symbols and definitions

Fig. 1: Schematic diagram to illustrate the structure of the index file. Consecutive index blocks each of size $\mathcal{N}^{\mathcal{F}_{idx}}$ contain the ordered sequence of indices for $\mathcal{D}^c$ as it appears in $\mathcal{F}_{in}$.

The file type of the data source is assumed to be in *ASCII* format. The input file containing signal data is denoted as $\mathcal{F}_{in}$. The number of characters in $\mathcal{F}_{in}$ is denoted as $\mathcal{N}^{\mathcal{F}_{in}}$. For a given character c when used as a data sample delimiter (or separator) is denoted as $\mathcal{D}^c$. A delimiter separated data sample $\mathbb{S}_k$ is defined as the sequence of characters between $(k-1)^{th}$ and k^{th} instance of $\mathcal{D}^c$ in $\mathcal{F}_{in}$ e.g. for *newline* as delimiter it is the sequence of

characters in the k^{th} line. Index of a character is the byte location of that character in a given file. The underlying operating system has $N = 64$ bit architecture². Index file denoted as $\mathcal{F}_{idx}$ is the file containing the indices of the $\mathcal{D}^c$. We make a convention that, the first line of the index file contains the meta information about the file and the rest of the file starting from the second line contains the indices.

2.2 Algorithm, dependencies and relationships

Three important C++ native functions [27], [28], [29] are the key drivers behind the functionalities of *GSFRS*. (a) *seekg*, (b) *tellg* and (c) *read*³. The *seekg* function sets the current open stream position to a specific target *byte location* on the *file-stream* whereas, *tellg* returns the current byte location of the open *file-stream* and *read*, reads a set number of characters from the current *byte location* to a temporary buffer array. *GSFRS* works in a two-step fashion, (a) indexing of $\mathcal{F}_{in}$ to produce $\mathcal{F}_{idx}$ and (b) sampling or parsing of k^{th} instance of $\mathbb{S}_k$. The primary goal of step (a) is to *find and store* the indices of $\mathcal{D}^c$ in an *index file* corresponding to $\mathcal{F}_{in}$. In order to do so in an efficient manner, we took advantage of the inherent *multi-threaded* architecture of modern microprocessors [30], [31]. A schematic representation of the index structure as recorded in $\mathcal{F}_{idx}$ is presented in Fig. 1. A representative snapshot of a typical $\mathcal{F}_{idx}$ is shown in Fig. 2. The quantitative details of the files are annotated within the representative figure. In order to execute multi-threaded processing, $\mathcal{F}_{in}$ is virtually divided into $\mathcal{N}^{\mathcal{B}}$ datablocks as defined in Eq. 1 so that each datablock can be delegated to an individual thread made available through the $\mathbb{m}$.

$$\mathcal{N}^{\mathcal{B}} = \text{ceil}\left(\frac{\mathcal{N}^{\mathcal{F}_{in}}}{\mathbb{m}}\right) \quad (1)$$

where, *ceiling* is the standard mathematical ceiling [32] function. k^{th} data-block is located between $(k-1) \times \mathbb{m}$ and $k \times \mathbb{m}$ byte locations. For each $\mathcal{B}_k$ we store the indices in a temporary index file $\mathcal{F}_{temp}$ created under */tmp*⁴ folder location of the host *OS*. Once all the threads complete the individual jobs, all the indices are merged into a single file $\mathcal{F}_{idx}$ in order followed by removal of all the instances of $\mathcal{F}_{temp}$. This way the memory footprint of the indexing operation is kept under control without significant penalty of efficiency as all the computationally heavy operations are done in the individual thread level. For the purpose of simplicity, we store the indices with base 10 system in $\mathcal{F}_{idx}$ in a consecutive fashion in order of appearance in $\mathcal{F}_{in}$. $\mathcal{F}_{idx}$ is structured such a way that, the number of place holding characters $\mathbb{m}$ to store the indices for all addressable space in $N = 64$ bit architecture is derived as shown below in Eq. 2.

$$\begin{aligned} \mathbb{m} &= \text{ceil}(N \times \log_{10}(2)) \\ &= 20 \end{aligned} \quad (2)$$

2. it is trivial to adapt to any other architecture types
3. or equivalently fread
4. or any other convenient location

Fig. 3: Indexing steps for a given input file $\mathcal{F}_{in}$ to create $\mathcal{F}_{idx}$

by closely mimicking realistic *EEG* signal sources but the signal values replaced by fixed width random numbers. For the purpose of testing and calibration we created 7 simulated signal files with 256 columns and 10, 100, 1000, 10000, 100000, 1000000, 10000000 rows respectively. Each signal element of these simulated files are generated using standard built-in random number generator with fixed number of 6 characters. Calculations related to performance of the software with respect to various relevant parameters were performed on these data sets. In order to perform software validation on a realistic data set, we used a long *EEG* data file with approximately one hour continuous recording time sampled at 2048 Hz.

3 RESULTS

The results are centered around the performance evaluation of *GSFRS* compared to existing gold standards and clock speed of the host machine. In order to evaluate the performance we used both *real world* and *simulated data*. Simulated data was designed and used for calibration and normalization of various relevant time scales whereas, real world experimental data was used to verify the utility of *GSFRS* in realistic scenarios. For the purpose of uniformity of time scales, all the numerical experiments were performed on the same machines under identical conditions. The machine configuration used for generating the results described

Fig. 4: Parsing steps of a data-block $\mathcal{B}_k$ from $\mathcal{F}_{in}$ by through $\mathcal{F}_{idx}$

here is *Apple Macbook Pro, 2019, 2.4 GHz 8-Core Intel Core i9*. Fig. 5 demonstrates the comparison of sampling time

Fig. 5: Comparison of sampling time between *GSFRS* and other standard tools like *awk*, *sed* for various data record locations (e.g. line numbers)

between *GSFRS* and other standard (unix or linux based) data access tools e.g. *awk* and *sed*. Interpolation lines are drawn to aid visual cue. For each point (e.g. number of samples) on the horizontal axis, 10 sampling instances were performed to calculate the mean and standard deviation of

the sampling times over those instances. Figs. 6 & 7 demon-

Fig. 6: Indexing time as a function of number of lines in the input file.

Fig. 7: Indexing time as a function of number of $\mathcal{N}^{\text{III}}$.

strate the indexing time with respect to various relevant parameters. Fig. 6 describes the indexing time (second) as a function of $\mathcal{N}^{\mathcal{D}^c}$ and Fig. 7 shows the indexing time for a fixed $\mathcal{F}_{in}$ but varying $\mathcal{N}^{\text{III}}$.

Similarly, Figs. 8 & 9 demonstrate the sampling time (sec) with respect to various relevant parameters. Fig. 8 describes the sampling time (sec) as a function of the $\mathcal{N}^{\mathcal{D}^c}$ for the simulated signal files described in sec. 2.5 and 9 describes the sampling time (sec) for fixed number of samples $\mathcal{N}^{\mathcal{S}}$ but varying $\mathcal{N}^{\text{III}}$.

Fig. 8: Sampling time vs number of lines in the $\mathcal{F}_{in}$

Fig. 9: Sampling time vs number of threads for a fixed number of samples

4 APPLICATION AREAS

Some potential application areas are listed below.

- 1) Medical devices [35], [36] for *on-the-fly* data indexing so that diagnostic outcomes can be produced at a rapid pace
- 2) Off the grid devices [37] requiring low energy footprint for query from large data-sets
- 3) Edge computing [38] and edge AI applications where low energy footprint and realtime access to collected data is an important criteria for reliable prediction
- 4) Space applications (e.g. NASA's MARS rovers) [39], [40] performing *on-the-fly* data analysis
- 5) Asynchronous query applications on remote devices
- 6) Real-time systems [41] for multi-threaded access to the same data source

5 DISCUSSION, STRENGTH AND LIMITATIONS

GSFRS enables us to have random access and sample any arbitrarily large *ASCII* file. In the context of a given processing task, only the necessary part of the data can be readily loaded on the memory for processing, without having to access any other part of the source. This is a significant advantage over line-by-line data access method followed in traditional tools like *grep*, *sed*, *awk* etc. where every instance of data reading involves reading the data from the beginning of the file followed by opening of the *file-stream*. These unused *data access instances* are effectively absorbed by the *OTI* process as demonstrated in Fig. 6. *OTI* can be efficiently performed by taking advantage of multi-threading architectures of modern microprocessors. The effect of III based indexing architecture is described in Fig. 7. The indexing time saturates to an optimal value as $\mathcal{N}^{\text{III}} \rightarrow \mathcal{N}^{\text{III}^*}$. The observation, that the performance actually degrades (although slightly), for $\mathcal{N}^{\text{III}}$ beyond $\mathcal{N}^{\text{III}^*}$ may seem apparently contradictory. One possible explanation is *context switching* [42] due to computational overload on a given hardware thread. A zig-zag pattern is observed for odd and even number of threads possibly attributed

to the way the *OS* and the microprocessor optimizes concurrent access to data streams. Fig. 8 demonstrates that, for relatively small number of samples, the sampling time does not vary much across various file sizes. For moderate range, the differences across file sizes are not very significant although for the file containing 100000 lines, there is a noticeable jump in the sampling time. It is clear that the computational cost⁷ gets overall higher as the number of samples increases. In Fig. 9, we observe that the query time is not strongly dependent on N^{iii} for relatively small file sizes but for the largest file, the multi-threaded query shows better performance with optimally higher number of N^{iii} . For small sizes of input files, the effective cost of query is dominated by the opening and closing of two files (e.g. $\mathcal{F}_{in}$ & $\mathcal{F}_{idx}$) as the cost of a *seekg*, call is nominal compared to *file-io* [43] costs.

From Fig. 5, it is clear that, data parsing gold standards like *awk* [44], [45], [46], *sed* [45], [47], [48], [49] however powerful, suffers from significantly longer access time compared to *GSFRS*. A potential integration of *GSFRS* with *awk*, *sed* would eventually turn these historically significant tools into very powerful and modern large scale data processing engines.

Simultaneous access to any random parts of the file is possible from arbitrarily large number of data processing units either through remote access or from processes on the same device. Also, the content of a given $\mathcal{F}_{idx}$ can be trivially modified to higher or lower bit architectures if it is mathematically consistent to do so. Porting from completely different *OS* architectures (e.g. Windows vs Linux) is as simple as copying the index file. Although, we have used *newline* as our record separator, it can be replaced by any other character separator specific to the need of a given data processing problem but without loss of generality. In future, we shall update the software to handle multiple characters as record separators as well as regular expression handlers. To preserve simplicity we allow only *ASCII* file but future development would generalize it to binary or other file types. From an algorithmic point of view, the query time should be independent of the file-size (or as independent as possible) however, from a hardware standpoint, there are certain limitations to this ideal scenario primarily due to the mechanism by which the *seekg*⁸ function finds the address location in a *block-by-block* fashion.

Although, we developed the algorithm to address the *large data file* random access problem, it can be also be used for *small data files* as well particularly for expensive, complex calculations like *ACF*, *MSD* etc. One of the immediate application area of this tool would be instant query embedded devices like *fitbit* [50], [51], *MUSE* [52], [53], wearable blood pressure monitor like *Glabella* [54] where intelligence is gathered from raw data samples collected through sensors within the device itself. One easy way to use this tool is to generate the index file *on-the-fly* so that, subsequent access won't necessitate reading the file from start again. Often, in the research community data is generated by one group of people (or devices) and analyzed

by various other groups under diverse contexts. In such scenarios, if the data is indexed right at the source, lot of computations (and energy) can be saved in the long run as we'll pay for only the accessed part of the data. We heavily utilized the *lock based multi-threaded* [55] built-in apis so that, the most computationally expensive part, indexing is done as fast as possible by optimally utilizing the available computational resources in a given computer. The choice of index file extension (see Sec. B) is arbitrary and can be trivially modified as per contextual processing need. Future development would include compression of the indices into binary files as well as random access to more granular level of data (e.g. words, matrix elements etc.). Existing computations using commercially available softwares like Matlab [56], [57], Mathematica [58], [59], Octave [60], [61] etc. would speed up significantly by interfacing with the *GSFRS*'s *get_sample* function through interfacing tools generally available as a feature of the commercial softwares. The biggest advantage of interfacing with *GSFRS* would be to have concurrent view of various data sections would be available either from multi-threaded or multi process [62], [63] environments. In realistic scenarios, large files should be indexed overnight right after recording of raw data if *on-the-fly* indexing is not possible. One important advantage of using *GSFRS* is a stupendous gain of computational efficiency and energy footprint by completely eliminating the need for redundant queries. It is to be noted that, some of the most computationally expensive operations performed during typical *big-data* driven calculations are, *cost of parsing* and maintenance of continuously running live databases. Under *GSFRS* philosophy of *index and parse*, once the indices are created it can be used or copied to other machines anytime in future without having to maintain a live database. With this advantage, all the redundant computations are made completely obsolete consistent with the philosophy *pay only for what you use*.

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⁷. in terms of computing time

⁸. <https://stackoverflow.com/questions/64904236/c-seekg-complexity>

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APPENDIX A SYMBOLS AND ACRONYMS

- 1) *GSFRS*: Giant Signal File Random Sampler
- 2) $\mathcal{B}_k$: Data-block k
- 3) $\mathcal{N}^{\mathcal{B}}$: Number of data blocks used to divide the characters in the input file for processing with $\llbracket \llbracket \llbracket$
- 4) $\mathcal{D}^c$: Delimiter character
- 5) $\mathcal{D}_k^c$: k^{th} occurrence of $\mathcal{D}^c$ in $\mathcal{F}_{in}$
- 6) $\mathcal{F}_{in}$: Input data file
- 7) $\mathcal{N}^{\mathcal{F}_{in}}$: Number of characters in $\mathcal{F}_{in}$
- 8) $\mathcal{F}_{idx}$: Index file
- 9) $\llbracket \llbracket \llbracket$: Threadpool
- 10) $\mathcal{N}^{\llbracket \llbracket \llbracket}$: Size of $\llbracket \llbracket \llbracket$ i.e. number of threads in $\llbracket \llbracket \llbracket$
- 11) $\llbracket \llbracket \llbracket$: Collection of hardware native threads available on the device
- 12) $\mathcal{N}^{\llbracket \llbracket \llbracket}$: Number of hardware threads
- 13) $\llbracket \llbracket \llbracket$: Number of characters to represent a given index in $\mathcal{F}_{idx}$
- 14) $\mathcal{I}_k^c$: Index location of $\mathcal{D}_k^c$
- 15) $\mathcal{N}^{\mathcal{I}_k^c}$: Numerical value of the k^{th} index located in $\mathcal{F}_{idx}$
- 16) N : OS architecture bits e.g. 64

APPENDIX B MISC. INFORMATION

The naming convention for $\mathcal{F}_{idx}$ is such that the $\mathcal{F}_{idx}$ name is same as $\mathcal{F}_{in}$ with added extension suffix *.idx*⁹. The file size of $\mathcal{F}_{idx}$ can be further reduced by storing the indices in *Hexadecimal format*¹⁰. In situations where simultaneous access to either $\mathcal{F}_{in}$ or $\mathcal{F}_{idx}$, from different threads of the host OS is necessary, a *file-stream* is opened specific to each thread using in-built C++ keyword *thread_local*. Although, we demonstrated the indexing process only for *newline* character, it can be easily extended to any other characters through a naming convention corresponding to each character. The information about the input files used for the numerical experiments are detailed in table 1. The source codebase is hosted at github¹¹. Documentation and other helpful details are provide at a the hosting location¹².

TABLE 1: Information containing numer of lines, input file size, and index file size

Serial	Data source	$\mathcal{N}^{\mathcal{D}^c}$	$\mathcal{N}^{\mathcal{F}_{in}}$	$\mathcal{N}^{\mathcal{F}_{idx}}$
1	BIOSEMI EEG ¹³	9963520	17GB	190MB
2	SIMULATED EEG	10	18KB	262B
3	SIMULATED EEG	100	176KB	2KB
4	SIMULATED EEG	1000	1.7MB	20KB
5	SIMULATED EEG	10000	17MB	195KB
6	SIMULATED EEG	100000	172MB	1.9MB
7	SIMULATED EEG	1000000	1.7GB	19MB
8	SIMULATED EEG	10000000	17GB	191MB

9. This choice is arbitrary

10. slated for a future version of the software

11. <https://github.com/gsfrs/gsfrsbase>

12. <https://gsfrs.github.io>

APPENDIX C SOFTWARE STRUCTURE

GSFRS is designed to be used as a standalone software as well as be integrated into other existing softwares by importing the *.hpp* header file. In its current version, the compiled executable would run from any standard terminal using simple *command line options* as described in Fig. 13 and more details are available in the software *README.md* file on the *github repo*. The code is entirely written in modern C++ programming language and the *command line options* are facilitated by opensource project *commandline*¹⁴ interface. The *commandline* interface is the entry point of various operations that can be pereformed with the software. The most important option is *./GSFRS -c $\mathcal{F}_{in}$* to create an index of $\mathcal{F}_{in}$. During the runtime of the index creation process each individual thread of $\llbracket \llbracket \llbracket$ is assigned the task of indexing a $\mathcal{B}_k$. After successful run of the *index creation process*, a new file with extension *.idx* would be generated at the location of $\mathcal{F}_{in}$ containing all the indices. The other important options are *-p* and *-r* respectively. *-p* is followed by the comma separated range structure sequence $n_1-n_2, n_3-n_4, n_5-n_6 \dots n_7-n_8$ etc. Each sample-range block n_k-n_l means the parsing of all the samples between n_k & n_l inclusive of the boundary points. Further details of the software would be made available on the github repository on the software documentation page.

APPENDIX D CODE SAMPLES

The function to get a single sample is described in Fig. 10. For multiple lines, a slightly modified version is demonstrated in Fig. 11 to facilitate a range query between a contiguous range of samples.

One of the most important function is the *index_creation*, as shown in Fig. 12. It performs the indexing and recording of indices on the disk. First, it creates a temporary file for each $\mathcal{B}_k$ and later concatenates them all to a single file $\mathcal{F}_{idx}$ as the *thread joining* step¹⁵. If the call to this function is successful $\mathcal{F}_{idx}$ is generated and made available to perform future query tasks. The temporary files containing indices for each $\mathcal{B}_k$ are removed from the disk when the *indexing tasks*, delegated to $\llbracket \llbracket \llbracket$ are successfully completed. Maintenance of the $\llbracket \llbracket \llbracket$ throughout the lifetime of the software, avoids the relatively expensive tasks of new thread creation and deletion. Smart-pointers are used whenever appropriate, to avoid unwanted memory leaks.

14. <https://github.com/jarro2783/cxxopts>

15. or equivalently the *reduce* step [64], [65] in *map-reduce* framework

```

// ULL = unsigned long long
/// @brief get a sample with sample_no as input
/// @param sample_no
/// @returns std::string
std::string GSFRS::get_sample(ULL sample_no){
    std::string str = "";
    ULL sample_no_corrected = {0};
    /// CALL ONCE BLOCK...DO THE INITIALIZATION OF PARAMETERS
    ///ONCE AND FOR ALL DURING THE LIFETIME OF INSTANTIATED GSFRS OBJECT
    //lambda expression to initialize params
    std::call_once(call_once_flag_, [this,&sample_no]){
        source_file_.open(source_filename_input_.c_str());
        if(!source_file_.good() || source_file_.eof()){
            std::cerr << "can't open file " << source_filename_input_ << std::endl;
            std::string err = {"file opening error"};
            throw err;
        }
        index_file_.open(index_filename_input_.c_str());
        if(!index_file_.good() || index_file_.eof()){
            std::cerr << index_filename_input_ << "could not be opened" << std::endl;
            std::string err = {"file opening error"};
            throw err;
        }
        std::getline(index_file_,header_);
        header_end_byte_location_ = std::move(index_file_.tellg());
        std::stringstream ss(header_.c_str());
        ss >> input_filename_in_index_file_;
        ss >> num_bytes_;
        ss >> num_lines_;
        ss >> precision_size_;
        empty_string_buffer_ = std::string(precision_size_, '0');
        if(num_lines_ < 1){
            std::cerr << "num lines <= 1 not allowed...";
            std::cerr << "program quit" << std::endl;
            exit(0);
        }
    });
    ///ONCE BLOCK ENDS
    // continued .....

```

Fig. 10: The *get_sample* function prototype to fetch a single data sample based on the sample number query identifier

```

/// @brief create the index of the input file
/// @returns void
void GSFRS::create_index(){
#ifdef IS_DEBUG
    std::cout << "in function " << __func__ << std::endl;
#endif
    create_random_temp_folder();
    minimal_multithreaded_byte_limit_ = 1;
    std::ifstream is;
    is.open(source_filename_.c_str(),std::ifstream::binary);
    if(is.good()){
        is.seekg(0,is.end);
        ULL length = is.tellg();
        is.seekg(0,is.beg);
        is.close();
        //boundary of indices
        std::vector<std::pair<ULL ,ULL>> thread_load_limits;
        ULL width=length/thread_pool_size_;
        if(width <= GSFRS::minimal_multithreaded_byte_limit_){
            thread_pool_size_ = 1;
            width=length;
        }
        std::pair<ULL ,ULL> temp_pair;
        for(unsigned i=0; i< thread_pool_size_; i++){
            temp_pair.first = std::move(i*width + 1);
            if(i==(thread_pool_size_-1))
                temp_pair.second=length;
            else
                temp_pair.second = std::move((i+1)*width);
            thread_load_limits.push_back(temp_pair);
        }
        std::map<ULL ,std::vector<ULL>> byte_location_master;
        int count=0;
        for(const auto& it:thread_load_limits){
            ++count;
            threadpool_runtime_futures_.emplace_back(threadpool_>enqueue(
                [this,it,count]()->decltype(auto){
                    std::string filename = temp_folder_hash_path_ + path_separator_ \
                    + program_name_string_ + "_" + "thread_block_" + std::to_string(count) \
                    + ".txt";
                    //Open to filestream to store the index locations
                    std::ofstream ofs(filename.c_str());
                    std::vector<ULL> byte_location;
                    std::ifstream filestream;
                    filestream.open(source_filename_.c_str(),std::ifstream::binary);
                    if(filestream.good()){
                        char c[2];
                        ULL begin=it.first;
                        ULL end=it.second;
                        filestream.seekg(begin);
                        for(ULL i=begin;i<=end;i++){
                            filestream.read(c,1);

```

Fig. 12: The *create_index* function prototype to create the index file $\mathcal{F}_{idx}$ from $\mathcal{F}_{in}$

```

/// @brief get multiple_samples
/// @returns std::vector<std::string>
template<typename T>
decltype(auto) GSFRS::get_multiple(const T& parse_vector){
    set_operation_label(GSFRS::Operations::GET_SAMPLES);
    std::vector<std::future<std::vector<std::string>>> parse_results;
    parse_results.reserve(parse_vector.size());
    for(const auto& it:parse_vector){
        // Perform the individual line parsing on a threadpool object
        parse_results.emplace_back(std::move(threadpool_>enqueue(
            // Lambda expression for single sample query
            [this,it]()->decltype(auto){
                std::vector<std::string> v;
                for(ULL i = std::get<0>(it); i<=std::get<1>(it);i++){
                    v.emplace_back(std::move(get_sample(i)));
                }
                return v;
            })));
    }
    std::vector<std::vector<std::string>> accumulated_result(parse_results.size());
    for( auto& parse_result:parse_results){
        accumulated_result.emplace_back(std::move(parse_result.get()));
    }
    return accumulated_result;
}

```

Fig. 11: The *get_sample* function prototype to get a multiple samples with a vector of sample numbers

command line options

Usage:

GSFRS [OPTION...] [optional args]

-c, --index	create index
-h, --help	help
-n, --num_threads arg	num threads
-p, --parse arg	parse line
-i, --input arg	file input
-r, --random_sampling arg	random sampling

Fig. 13: Built-in command line options of the GSFRS software