Praise be to Allah

Astor: A Practical Parallel Antivirus Engine

Initial Report

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Statement of Problem

While scanning files, H.D.D is system's bottleneck. Since it provides a small amount of data, there will be no need for parallelization, i.e**. it is not worthwhile to implement a concurrent engine**.

Solution

Making it worthwhile by trying to improve the read speed of the drive.

Technical Approach

There is a technology used in hard disk drives, named NCQ (Native Command Queuing). If we send read requests for the H.D.D controller, e.g. Read requests for files A, B, C and D then the device starts reading the file which is nearest to the Head, not the file which has been sent first.

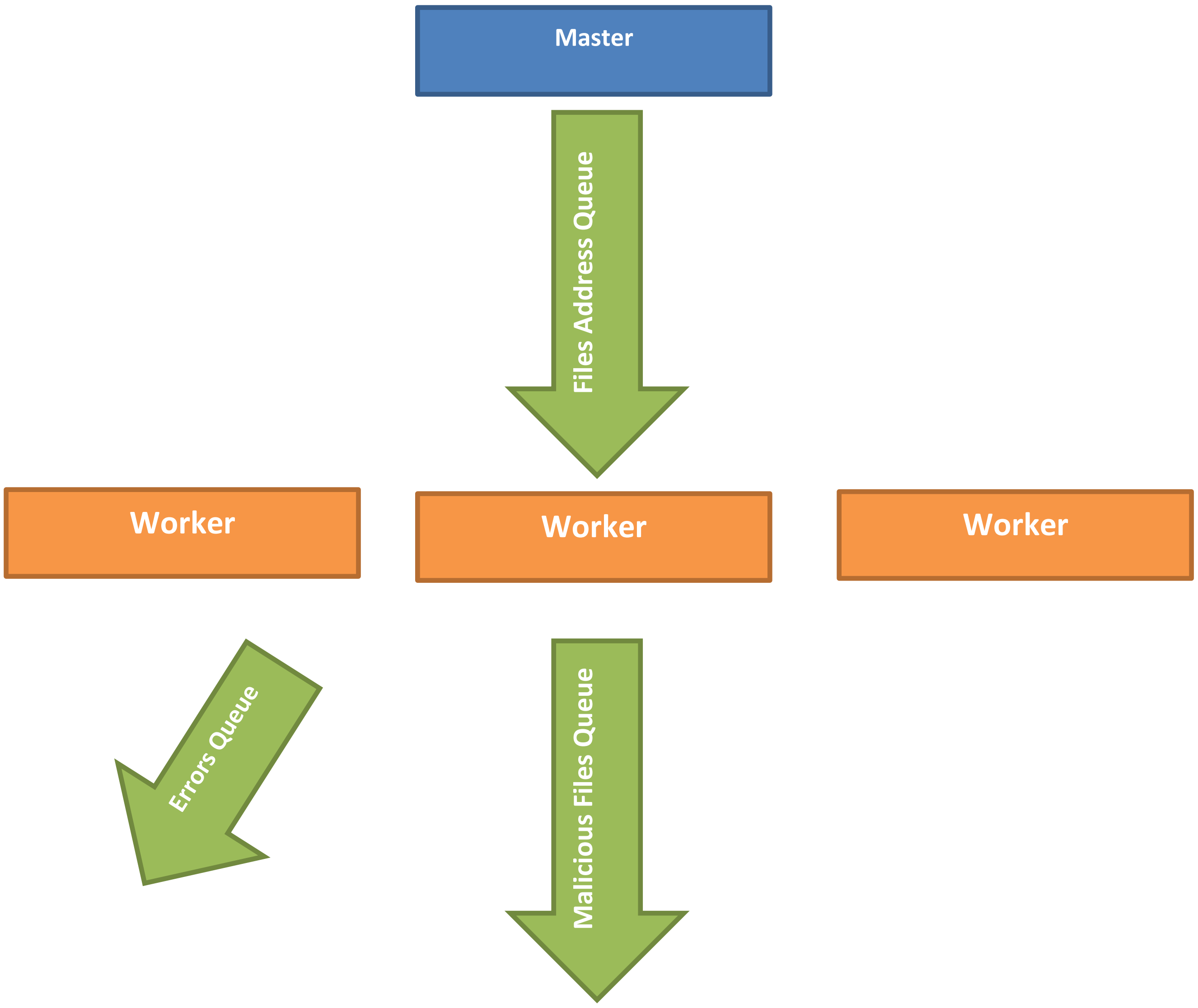
Implementation

I implemented a signature based AV engine (VeronicaAV) to test the idea. There are 5 revisions of the engine in Appendix A but I will explain the architecture of the latest version.

- We have <u>a master</u> thread and <u>10 worker threads.</u>
- Master: Collects all the file addresses in the given directory and inserts them in a global queue.
- Workers: Each worker Takes one file, scans it then goes for the next file address in the global queue.
- Workers insert the malicious files into a separated queue. They also insert the occurred errors into the global error queue.
- The master thread listens to the malicious files queue as well as error queue.

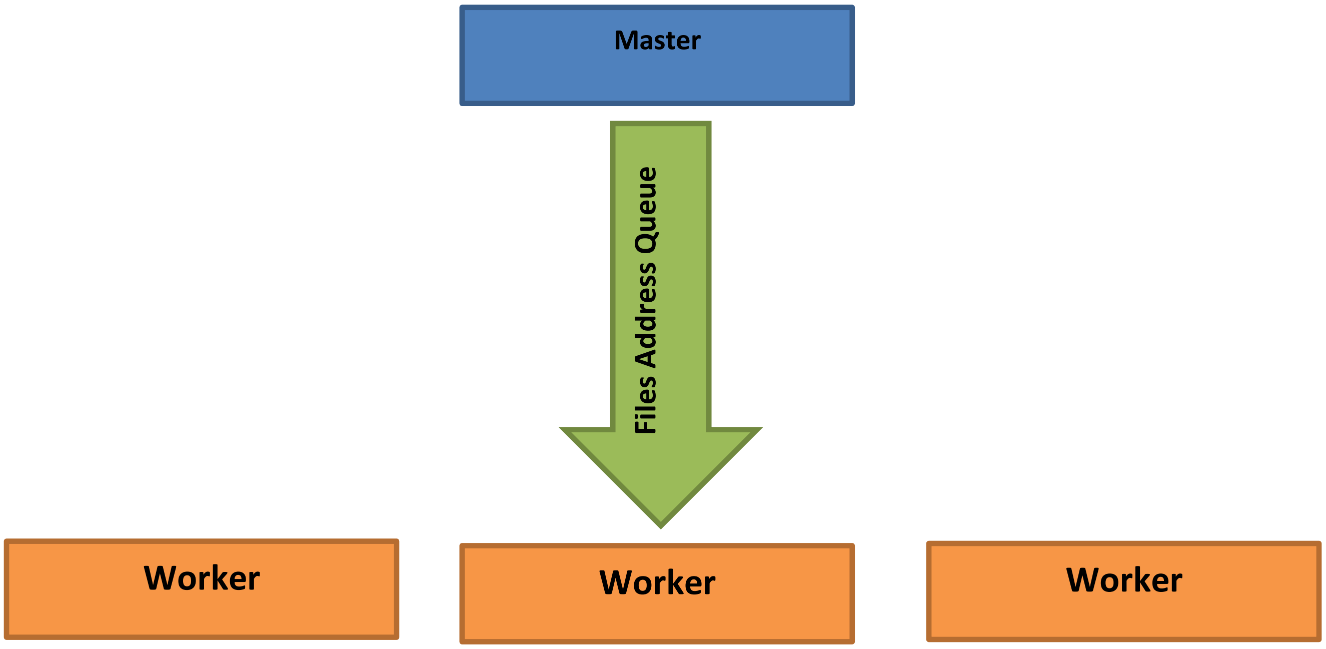
(Actually the true concurrency of my system is 4 threads simultaneously but as I was working with I/O I could achieve a better result with more threads.)

This way we have several requests sent to the H.D.D approximately at the same time.



The Final Architecture

I am still studying concurrency in C++ programming language, thus to test the idea I implemented a very simple and naïve implementation which looks like this:



Current Implementation

And here are the results. I have tested the implementation on 2 different systems and I have rebooted the system to take every sample.

System 1

Directory: C:\Python27 (Python 2.7.3)

Size: 43.7794 MB

#Files: 3158 Files

	Elapsed Time (Second)	Average Speed (MB/Second)
WinC++.cpp (Simple Sequential Implementation Using Win32 APIs)	47.1820	0.9279
WinC++_Queue_MultiThreaded.cpp (Using a global queue and 4 threads)	26.6940	1.6400
WinC++_Queue_MultiThreaded.cpp (Using a global queue and 10 threads)	24.3020	1.8015

Speed-up: 1.94X

System 2

Directory: C:\Python27 (Python 2.7.3)

+ Plugins & Extensions

Size: 69.50 MB

#Files: 7492 Files

	Elapsed Time (Second)	Average Speed (MB/Second)
WinC++.cpp (Simple Sequential Implementation Using Win32 APIs)	199.5140	0.3483
WinC++_Queue_MultiThreaded.cpp (Using a global queue and 10 threads)	54.4840	1.2756

Speed-up: 3.66X

Implementation Pitfalls:

- Although I've improved the read speed, but the implementation is very basic, I did not even have a thread-safe queue for C++.
- There are a lot of prints on the screen done by worker threads, which may decrease the overall performance of the program.
- The master thread collects all the addresses before workers begin their work; it's not a good idea.
- Etc.

Big Question

- **Why this method is not used in ClamAV?**

  I do not have the answer yet.

Next Step

I have to implement something similar inside ClamAV for further studies.

Appendix A

WinC++.cpp

Sequential Version

```
#include <Windows.h>
#include <ctime>
#include <iostream>
#include <string>
#include <new>
#include <sstream>

using namespace std;

enum class ReturnCode { VAV_FALUIRE, VAV_SUCCESS };
enum class LogCode {
PRINT_FINAL_RESULTS,READ_FILE_ERR,DIR_NOT_FOUND,MEM_ALOC_FILE_ERR,OPEN_SIGN_FILE_ERR,MEM_
ALOC_SIGN_FILE_ERR,OPEN_FILE_ERR,AFFECTED_FILE,CLEAN_FILE };

struct File {
	BYTE *pFile;
	LARGE_INTEGER FileSize;
	string Target;
	HANDLE hFileStream;
	ReturnCode Release();
};

ReturnCode File::Release(){
	delete[] pFile;
	CloseHandle(hFileStream);
	return ReturnCode::VAV_SUCCESS;
}

struct SignatureDatabase {
	BYTE *pDatabase;
	DWORD DatabaseSize;
	string Target;
	HANDLE hFile;
	ReturnCode Release();
};

ReturnCode SignatureDatabase::Release(){
	delete[] pDatabase;
	CloseHandle(hFile);
	return ReturnCode::VAV_SUCCESS;
}

struct ScanResult {
	SIZE_T Detected;
	SIZE_T TotalScanned;
	SIZE_T Errors;
	FLOAT Clock;
	ULONG ScanSize;
	FLOAT ElapsedTime() { return (clock() - Clock)/CLOCKS_PER_SEC; };
	FLOAT AverageSizePerTime(){ return ScanSizeInMB() / ElapsedTime(); };
	FLOAT ScanSizeInMB(){return ScanSize / (1024.0*1024); };
	VOID Reset() { Clock = clock() ; ScanSize = 0; Detected = 0 ;  TotalScanned = 0 ;
Errors = 0; };
	ScanResult() : Clock(clock()) , ScanSize(0) , Detected(0) , TotalScanned(0) ,
Errors(0){};
};

/******************** Global Variables ********************/
ScanResult                   GlobalScanResult;
SignatureDatabase    GlobalSignatureDatabase;
/*********************************************************/

VOID Log(LogCode Code, const string& Argument = ""){
	switch(Code){
	case LogCode::PRINT_FINAL_RESULTS:
		printf(" -----------------------------------------------------------------
\n");
		printf("|              # Scanned  Files   : %-10d  File(s)
|\n",GlobalScanResult.TotalScanned);
		printf("|              # Detected Files   : %-10d  File(s)
|\n",GlobalScanResult.Detected);
		printf("|              # Occured Errors   : %-10d  File(s)
|\n",GlobalScanResult.Errors);
		printf("|              # Elapsed Time     : %-10.4f  Second(s)
|\n",GlobalScanResult.ElapsedTime());
		printf("|              # Scan Size        : %-10.4f  MB
|\n",GlobalScanResult.ScanSizeInMB());
		printf("|              # Size/Time        : %-10.4f  MB/S
|\n",GlobalScanResult.AverageSizePerTime());
		printf(" -----------------------------------------------------------------
\n");
		break;
	case LogCode::READ_FILE_ERR:
		cout << "[-] Error While Reading File : \'" <<
strrchr(Argument.c_str(),'\\') + 1 << "'\n";
		break;
	case LogCode::DIR_NOT_FOUND:
		cout << "[-] Directory Not Found : \'" << Argument << "'\n";
		break;
	case LogCode::MEM_ALOC_FILE_ERR:
		cout << "[-] Error While Allocating Memory For File : \'" <<
strrchr(Argument.c_str(),'\\') + 1 << "'\n";
		break;
	case LogCode::OPEN_SIGN_FILE_ERR:
		cout << "[-] Error While Opening The Signature File.\n";
		break;
```

```
        case LogCode::MEM_ALOC_SIGN_FILE_ERR:
                cout << "[-] Error While Allocating Memory For The Signature File.\n";
                break;
        case LogCode::OPEN_FILE_ERR:
                cout << "[-] Error While Opening File : \'" <<
strrchr(Argument.c_str(),'\\') + 1 << "'\n";
                break;
        case LogCode::AFFECTED_FILE:
                cout << "[-] AFFECTED  : " << strrchr(Argument.c_str(),'\\') + 1 << "\n";
                break;
        case LogCode::CLEAN_FILE:
                cout << "[-] CLEAN     : " << strrchr(Argument.c_str(),'\\') + 1 << "\n";
                break;
        }
}

//      Converting a One Byte Hex String To Its Equivalent Integer Value.
INT OneByteAsciiHexToInt(CHAR *String){
        INT i=0,Value=0;
        while(String[i] != '\0'){
                if(String[i] >= 'A' && String[i] <= 'F'){
                        Value += (String[i]-'A' + 10)*(pow((DOUBLE)16,(INT)1-i));
                }else if(String[i] >= 'a' && String[i] <= 'f'){
                        Value += (String[i]-'a' + 10)*(pow((DOUBLE)16,(INT)1-i));
                }else{
                        Value += (String[i]-'0')*(pow((DOUBLE)16,(INT)1-i));
                }
                i++;
        }
        return Value;
}

VOID ConsoleInitializer(VOID){
        SetConsoleTitle(L"Veronica Antivirus");
        cout << " ------------------------------------------------------------- \n";
        cout << "|                      Veronica Antivirus                     |\n";
        cout << "|                  Written By Ahmad Siavashi                  |\n";
        cout << "|                 Email : a.siavosh@yahoo.com                 |\n";
        cout << "|                      Shiraz  University                     |\n";
        cout << "|                         Spring 2012                         |\n";
        cout << " ------------------------------------------------------------- \n";
}

//      String Matching Algorithm.
bool DetectSignatureInFile(File * pFile){
        for(int i=0;i<pFile->FileSize.QuadPart;i++){
                int j,k;
                if(pFile->pFile[i] == GlobalSignatureDatabase.pDatabase[0]){
                        for(j=1,k=i+1;j < GlobalSignatureDatabase.DatabaseSize && k < pFile-
>FileSize.QuadPart;j++,k++){
                                if(GlobalSignatureDatabase.pDatabase[j] != pFile->pFile[k])
                                        break;
                        }
                        if(j == GlobalSignatureDatabase.DatabaseSize){
                                return true;
                        }
                }
        }
        return false;
}

//      Obtaining The Signature File.
ReturnCode LoadSignature(string& SignatureFileName){
        INT i=0,j=0,c='\0',k=0;
        CHAR aChar[3];
        CHAR *pReadBuffer;
        DWORD dwBytesRead;
        LARGE_INTEGER FileSize;
        GlobalSignatureDatabase.Target = string(SignatureFileName);
        if((GlobalSignatureDatabase.hFile =
CreateFileA(SignatureFileName.c_str(),GENERIC_READ,FILE_SHARE_READ,NULL,OPEN_EXISTING,FIL
E_ATTRIBUTE_NORMAL | FILE_FLAG_NO_BUFFERING | FILE_FLAG_WRITE_THROUGH ,NULL)) ==
INVALID_HANDLE_VALUE){
                Log(LogCode::OPEN_SIGN_FILE_ERR);
                system("PAUSE");
                exit(EXIT_FAILURE);
        }
        GetFileSizeEx(GlobalSignatureDatabase.hFile,&FileSize);
        GlobalSignatureDatabase.DatabaseSize = (FileSize.QuadPart+1)/3;
        if((GlobalSignatureDatabase.pDatabase = new (nothrow)
BYTE[int(ceil((float)FileSize.QuadPart / 512)*512)])==nullptr){
                Log(LogCode::MEM_ALOC_SIGN_FILE_ERR);
                system("PAUSE");
                exit(EXIT_FAILURE);
        }
        pReadBuffer = new (nothrow) CHAR[FileSize.QuadPart];
        ReadFile(GlobalSignatureDatabase.hFile,pReadBuffer,ceil((float)FileSize.QuadPart /
512)*512, &dwBytesRead,nullptr);
        while((c=pReadBuffer[k]) != '\n' && c!=EOF && k++ <= dwBytesRead){
                if(c != ' '){
                        aChar[j++] = c;
                        if(j==2){
                                aChar[j] = '\0';
                                GlobalSignatureDatabase.pDatabase[i] =
OneByteAsciiHexToInt(aChar);
                                j = 0;
                                i++;
                        }
                }
        }
        delete[] pReadBuffer;
        return ReturnCode::VAV_SUCCESS;
}

File * LoadFile(CONST CHAR *FileName){
        File * pFile = new File;
        pFile->Target = string(FileName);
        if((pFile->hFileStream = CreateFileA(pFile-
>Target.c_str(),GENERIC_READ,FILE_SHARE_READ,NULL,OPEN_EXISTING,FILE_ATTRIBUTE_NORMAL |
FILE_FLAG_NO_BUFFERING | FILE_FLAG_WRITE_THROUGH,NULL))==INVALID_HANDLE_VALUE){
                Log(LogCode::OPEN_FILE_ERR,pFile->Target);
                delete pFile;
                return nullptr;
        }

        DWORD dwBytesRead;
```

```
	GetFileSizeEx(pFile->hFileStream,&pFile->FileSize);
	if((pFile->pFile = new BYTE[int(ceil((float)pFile->FileSize.QuadPart / 512)*512)])
== NULL){
		Log(LogCode::MEM_ALOC_FILE_ERR,pFile->Target);
		delete pFile;
		return nullptr;
	}

	if(ReadFile(pFile->hFileStream,pFile->pFile,ceil((float)pFile->FileSize.QuadPart /
512)*512, &dwBytesRead,NULL) == 0){
		Log(LogCode::READ_FILE_ERR,pFile->Target);
		free(pFile->pFile);
		delete pFile;
		return nullptr;
	}
	return pFile;
}

bool ScanDirectoryFiles(CHAR * Dir){
	HANDLE				hFindFile;
	File	*			pFile = nullptr;
	WIN32_FIND_DATAA	Win32FindData;
	CHAR				Directory[MAX_PATH];

	sprintf(Directory,"%s\\*.*",Dir);
	if((hFindFile=FindFirstFileA(Directory,&Win32FindData))==INVALID_HANDLE_VALUE){
		Log(LogCode::DIR_NOT_FOUND,Dir);
		return false;
	}

	do{
		if(strcmp(Win32FindData.cFileName,".") != 0 &&
strcmp(Win32FindData.cFileName,"..") != 0){
			sprintf(Directory,"%s\\%s",Dir,Win32FindData.cFileName);
			if(Win32FindData.dwFileAttributes & FILE_ATTRIBUTE_DIRECTORY){
				ScanDirectoryFiles(Directory);
			}else{
				if((pFile = LoadFile(Directory)) != nullptr){
					if(DetectSignatureInFile(pFile)){
						GlobalScanResult.Detected++;
						Log(LogCode::AFFECTED_FILE,Directory);
					}else{
						Log(LogCode::CLEAN_FILE,Directory);
					}
					GlobalScanResult.TotalScanned++;
					GlobalScanResult.ScanSize += pFile->FileSize.QuadPart;
					pFile->Release();
					delete pFile;

					CHAR ConsoleTitle[MAX_PATH];
					sprintf(ConsoleTitle,"VAV - %d File(s) Scanned : %d
File(s) Detected - %d Error(s)
Occurred\n",GlobalScanResult.TotalScanned,GlobalScanResult.Detected,GlobalScanResult.Erro
rs);
					SetConsoleTitleA(ConsoleTitle);
				}else{
					GlobalScanResult.Errors++;
```

```
                            }
                    }
            }
    }while(FindNextFileA(hFindFile,&Win32FindData));
    FindClose(hFindFile);
    return TRUE;
}

INT main(){
    ConsoleInitializer();
    LoadSignature(string("signature.txt"));
    stringstream Args(" ");
    string Cmd,temp,Line,Directory("C:\\");
    cout << "For more information, type 'help'." << endl;
    do {
            cout << ">> ";
            getline(cin,Line);
            Args.clear();
            Args << Line;
            Cmd.erase();
            Args >> Cmd;

            if(Cmd == "exit"){
                    break;
            }else if(Cmd == "help"){
                    cout << "exit" << endl;
                    cout << "scan <dir>" << endl;
            }else if(Cmd == "scan"){
                    Args >> temp;
                    if(temp != "-"){
                            Directory = temp;
                    }
                    GlobalScanResult.Reset();
                    ScanDirectoryFiles((CHAR *)Directory.c_str());
                    Log(LogCode::PRINT_FINAL_RESULTS);
            }
    }while(true);
    GlobalSignatureDatabase.Release();
    return EXIT_SUCCESS;
}
```

WinC++_Queue_MultiThreaded.cpp

Final Version (10 Threads)

```
#include <Windows.h>
#include <ctime>
#include <iostream>
#include <string>
#include <new>
#include <sstream>
```

```
#include <thread>
#include <mutex>
#include <queue>

using namespace std;

enum class ReturnCode { VAV_FALUIRE, VAV_SUCCESS };
enum class LogCode {
PRINT_FINAL_RESULTS,READ_FILE_ERR,DIR_NOT_FOUND,MEM_ALOC_FILE_ERR,OPEN_SIGN_FILE_ERR,MEM_
ALOC_SIGN_FILE_ERR,OPEN_FILE_ERR,AFFECTED_FILE,CLEAN_FILE };

struct File {
	BYTE *pFile;
	LARGE_INTEGER FileSize;
	string Target;
	HANDLE hFileStream;
	ReturnCode Release();
};

ReturnCode File::Release(){
	delete[] pFile;
	CloseHandle(hFileStream);
	return ReturnCode::VAV_SUCCESS;
}

struct SignatureDatabase {
	BYTE *pDatabase;
	DWORD DatabaseSize;
	string Target;
	HANDLE hFile;
	ReturnCode Release();
};

ReturnCode SignatureDatabase::Release(){
	delete[] pDatabase;
	CloseHandle(hFile);
	return ReturnCode::VAV_SUCCESS;
}

struct ScanResult {
	SIZE_T Detected;
	SIZE_T TotalScanned;
	SIZE_T Errors;
	FLOAT Clock;
	ULONG ScanSize;
	FLOAT ElapsedTime() { return (clock() - Clock)/CLOCKS_PER_SEC; };
	FLOAT AverageSizePerTime(){ return ScanSizeInMB() / ElapsedTime(); };
	FLOAT ScanSizeInMB(){return ScanSize / (1024.0*1024); };
	VOID Reset() { Clock = clock() ; ScanSize = 0; Detected = 0 ;  TotalScanned = 0 ;
Errors = 0; };
	ScanResult() : Clock(clock()) , ScanSize(0) , Detected(0) , TotalScanned(0) ,
Errors(0){};
};

/******************** Global Variables *********************/
ScanResult                 GlobalScanResult;
SignatureDatabase    GlobalSignatureDatabase;
queue<string>        DirectoryQueue;
```

```
mutex                       QueueMutex;
/************************************************************/

VOID Log(LogCode Code, const string& Argument = ""){
       switch(Code){
       case LogCode::PRINT_FINAL_RESULTS:
              printf(" -----------------------------------------------------------------
\n");
              printf("|              # Scanned  Files   : %-10d  File(s)
|\n",GlobalScanResult.TotalScanned);
              printf("|              # Detected Files   : %-10d  File(s)
|\n",GlobalScanResult.Detected);
              printf("|              # Occured Errors   : %-10d  File(s)
|\n",GlobalScanResult.Errors);
              printf("|              # Elapsed Time     : %-10.4f  Second(s)
|\n",GlobalScanResult.ElapsedTime());
              printf("|              # Scan Size        : %-10.4f  MB
|\n",GlobalScanResult.ScanSizeInMB());
              printf("|              # Size/Time        : %-10.4f  MB/S
|\n",GlobalScanResult.AverageSizePerTime());
              printf(" -----------------------------------------------------------------
\n");
              break;
       case LogCode::READ_FILE_ERR:
              cout << "[-] Error While Reading File : \'" <<
strrchr(Argument.c_str(),'\\') + 1 << "'\n";
              break;
       case LogCode::DIR_NOT_FOUND:
              cout << "[-] Directory Not Found : \'" << Argument << "'\n";
              break;
       case LogCode::MEM_ALOC_FILE_ERR:
              cout << "[-] Error While Allocating Memory For File : \'" <<
strrchr(Argument.c_str(),'\\') + 1 << "'\n";
              break;
       case LogCode::OPEN_SIGN_FILE_ERR:
              cout << "[-] Error While Opening The Signature File.\n";
              break;
       case LogCode::MEM_ALOC_SIGN_FILE_ERR:
              cout << "[-] Error While Allocating Memory For The Signature File.\n";
              break;
       case LogCode::OPEN_FILE_ERR:
              cout << "[-] Error While Opening File : \'" <<
strrchr(Argument.c_str(),'\\') + 1 << "'\n";
              break;
       case LogCode::AFFECTED_FILE:
              cout << "[-] AFFECTED  : " << strrchr(Argument.c_str(),'\\') + 1 << "\n";
              break;
       case LogCode::CLEAN_FILE:
              cout << "[-] CLEAN     : " << strrchr(Argument.c_str(),'\\') + 1 << "\n";
              break;
       }
}

//     Converting a One Byte Hex String To Its Equivalent Integer Value.
INT OneByteAsciiHexToInt(CHAR *String){
       INT i=0,Value=0;
       while(String[i] != '\0'){
              if(String[i] >= 'A' && String[i] <= 'F'){
```

```
                        Value += (String[i]-'A' + 10)*(pow((DOUBLE)16,(INT)1-i));
                }else if(String[i] >= 'a' && String[i] <= 'f'){
                        Value += (String[i]-'a' + 10)*(pow((DOUBLE)16,(INT)1-i));
                }else{
                        Value += (String[i]-'0')*(pow((DOUBLE)16,(INT)1-i));
                }
                i++;
        }
        return Value;
}

VOID ConsoleInitializer(VOID){
        SetConsoleTitle(L"Veronica Antivirus");
        cout << " ------------------------------------------------------------ \n";
        cout << "|                      Veronica Antivirus                      |\n";
        cout << "|                  Written By Ahmad Siavashi                   |\n";
        cout << "|                 Email : a.siavosh@yahoo.com                  |\n";
        cout << "|                      Shiraz  University                      |\n";
        cout << "|                         Spring 2012                          |\n";
        cout << " ------------------------------------------------------------ \n";
}

//      String Matching Algorithm.
bool DetectSignatureInFile(File * pFile){
        for(int i=0;i<pFile->FileSize.QuadPart;i++){
                int j,k;
                if(pFile->pFile[i] == GlobalSignatureDatabase.pDatabase[0]){
                        for(j=1,k=i+1;j < GlobalSignatureDatabase.DatabaseSize && k < pFile-
>FileSize.QuadPart;j++,k++){
                                if(GlobalSignatureDatabase.pDatabase[j] != pFile->pFile[k])
                                        break;
                        }
                        if(j == GlobalSignatureDatabase.DatabaseSize){
                                return true;
                        }
                }
        }
        return false;
}

//      Obtaining The Signature File.
ReturnCode LoadSignature(string& SignatureFileName){
        INT i=0,j=0,c='\0',k=0;
        CHAR aChar[3];
        CHAR *pReadBuffer;
        DWORD dwBytesRead;
        LARGE_INTEGER FileSize;
        GlobalSignatureDatabase.Target = string(SignatureFileName);
        if((GlobalSignatureDatabase.hFile =
CreateFileA(SignatureFileName.c_str(),GENERIC_READ,FILE_SHARE_READ,NULL,OPEN_EXISTING,FIL
E_ATTRIBUTE_NORMAL | FILE_FLAG_NO_BUFFERING | FILE_FLAG_WRITE_THROUGH ,NULL)) ==
INVALID_HANDLE_VALUE){
                Log(LogCode::OPEN_SIGN_FILE_ERR);
                system("PAUSE");
                exit(EXIT_FAILURE);
        }
        GetFileSizeEx(GlobalSignatureDatabase.hFile,&FileSize);
        GlobalSignatureDatabase.DatabaseSize = (FileSize.QuadPart+1)/3;
```

```
	if((GlobalSignatureDatabase.pDatabase = new (nothrow)
BYTE[int(ceil((float)FileSize.QuadPart / 512)*512)])==nullptr){
		Log(LogCode::MEM_ALOC_SIGN_FILE_ERR);
		system("PAUSE");
		exit(EXIT_FAILURE);
	}
	pReadBuffer = new (nothrow) CHAR[FileSize.QuadPart];
	ReadFile(GlobalSignatureDatabase.hFile,pReadBuffer,ceil((float)FileSize.QuadPart /
512)*512, &dwBytesRead,nullptr);
	while((c=pReadBuffer[k]) != '\n' && c!=EOF && k++ <= dwBytesRead){
		if(c != ' '){
			aChar[j++] = c;
			if(j==2){
				aChar[j] = '\0';
				GlobalSignatureDatabase.pDatabase[i] =
OneByteAsciiHexToInt(aChar);
				j = 0;
				i++;
			}
		}
	}
	delete[] pReadBuffer;
	return ReturnCode::VAV_SUCCESS;
}

File * LoadFile(CONST CHAR *FileName){
	File * pFile = new File;
	pFile->Target = string(FileName);
	if((pFile->hFileStream = CreateFileA(pFile-
>Target.c_str(),GENERIC_READ,FILE_SHARE_READ,NULL,OPEN_EXISTING,FILE_ATTRIBUTE_NORMAL |
FILE_FLAG_NO_BUFFERING | FILE_FLAG_WRITE_THROUGH,NULL))==INVALID_HANDLE_VALUE){
		Log(LogCode::OPEN_FILE_ERR,pFile->Target);
		delete pFile;
		return nullptr;
	}

	DWORD dwBytesRead;

	GetFileSizeEx(pFile->hFileStream,&pFile->FileSize);
	if((pFile->pFile = new BYTE[int(ceil((float)pFile->FileSize.QuadPart / 512)*512)])
== NULL){
		Log(LogCode::MEM_ALOC_FILE_ERR,pFile->Target);
		delete pFile;
		return nullptr;
	}

	if(ReadFile(pFile->hFileStream,pFile->pFile,ceil((float)pFile->FileSize.QuadPart /
512)*512, &dwBytesRead,NULL) == 0){
		Log(LogCode::READ_FILE_ERR,pFile->Target);
		free(pFile->pFile);
		delete pFile;
		return nullptr;
	}
	return pFile;
}

bool QueueDirectoryFiles(CHAR * Dir){
	HANDLE				hFindFile;
```

```
        WIN32_FIND_DATAA     Win32FindData;
        CHAR                        Directory[MAX_PATH];

        sprintf(Directory,"%s\\*.*",Dir);
        if((hFindFile=FindFirstFileA(Directory,&Win32FindData))==INVALID_HANDLE_VALUE){
                Log(LogCode::DIR_NOT_FOUND,Dir);
                return false;
        }

        do{
                if(strcmp(Win32FindData.cFileName,".") != 0 &&
strcmp(Win32FindData.cFileName,"..") != 0){
                        sprintf(Directory,"%s\\%s",Dir,Win32FindData.cFileName);
                        if(Win32FindData.dwFileAttributes & FILE_ATTRIBUTE_DIRECTORY){
                                QueueDirectoryFiles(Directory);
                        }else{
                                DirectoryQueue.push(string(Directory));
                        }
                }
        }while(FindNextFileA(hFindFile,&Win32FindData));
        FindClose(hFindFile);
        return TRUE;
}

VOID ScanFile(){
        while(true){
                QueueMutex.lock();
                if(DirectoryQueue.empty()) break;
                string FileName = DirectoryQueue.front();
                DirectoryQueue.pop();
                QueueMutex.unlock();
                File * pFile = nullptr;
                if((pFile = LoadFile((const char *)FileName.c_str())) != nullptr){
                        if(DetectSignatureInFile(pFile)){
                                GlobalScanResult.Detected++;
                                Log(LogCode::AFFECTED_FILE,FileName);
                        }else{
                                Log(LogCode::CLEAN_FILE,FileName);
                        }
                        GlobalScanResult.TotalScanned++;
                        GlobalScanResult.ScanSize += pFile->FileSize.QuadPart;
                        pFile->Release();
                        delete pFile;

                        CHAR ConsoleTitle[MAX_PATH];
                        sprintf(ConsoleTitle,"VAV - %d File(s) Scanned : %d File(s) Detected
- %d Error(s)
Occurred\n",GlobalScanResult.TotalScanned,GlobalScanResult.Detected,GlobalScanResult.Erro
rs);
                        SetConsoleTitleA(ConsoleTitle);
                        /**/
                }else{
                        GlobalScanResult.Errors++;
                }
                /**/
        }
        if(!QueueMutex.try_lock())
                QueueMutex.unlock();
```

```
}

VOID Scan(string Directory){
	GlobalScanResult.Reset();
	QueueDirectoryFiles((CHAR *) Directory.c_str());
	vector<thread> threads(10);
	threads[0] = thread(ScanFile);
	threads[1] = thread(ScanFile);
	threads[2] = thread(ScanFile);
	threads[3] = thread(ScanFile);
	threads[4] = thread(ScanFile);
	threads[5] = thread(ScanFile);
	threads[6] = thread(ScanFile);
	threads[7] = thread(ScanFile);
	threads[8] = thread(ScanFile);
	threads[9] = thread(ScanFile);
	for_each(threads.begin(),threads.end(),std::mem_fn(&thread::join));
}

INT main(){
	ConsoleInitializer();
	LoadSignature(string("signature.txt"));
	stringstream Args(" ");
	string Cmd,temp,Line,Directory("C:\\");
	cout << "For more information, type 'help'." << endl;
	do {
		cout << ">> ";
		getline(cin,Line);
		Args.clear();
		Args << Line;
		Cmd.erase();
		Args >> Cmd;

		if(Cmd == "exit"){
			break;
		}else if(Cmd == "help"){
			cout << "exit" << endl;
			cout << "scan <dir>" << endl;
		}else if(Cmd == "scan"){
			Args >> temp;
			if(temp != "-"){
				Directory = temp;
			}
			Scan(Directory);
			Log(LogCode::PRINT_FINAL_RESULTS);
		}
	}while(true);
	GlobalSignatureDatabase.Release();
	return EXIT_SUCCESS;
}
```

------------------------------ Older Implementations ----------------------------

WinC++_Queue.cpp

Sequential + Gathering Addresses at first

```
#include <Windows.h>
#include <ctime>
#include <iostream>
#include <string>
#include <new>
#include <sstream>
#include <queue>

using namespace std;

enum class ReturnCode { VAV_FALUIRE, VAV_SUCCESS };
enum class LogCode {
PRINT_FINAL_RESULTS,READ_FILE_ERR,DIR_NOT_FOUND,MEM_ALOC_FILE_ERR,OPEN_SIGN_FILE_ERR,MEM_
ALOC_SIGN_FILE_ERR,OPEN_FILE_ERR,AFFECTED_FILE,CLEAN_FILE };

struct File {
	BYTE *pFile;
	LARGE_INTEGER FileSize;
	string Target;
	HANDLE hFileStream;
	ReturnCode Release();
};

ReturnCode File::Release(){
	delete[] pFile;
	CloseHandle(hFileStream);
	return ReturnCode::VAV_SUCCESS;
}

struct SignatureDatabase {
	BYTE *pDatabase;
	DWORD DatabaseSize;
	string Target;
	HANDLE hFile;
	ReturnCode Release();
};

ReturnCode SignatureDatabase::Release(){
	delete[] pDatabase;
	CloseHandle(hFile);
	return ReturnCode::VAV_SUCCESS;
}

struct ScanResult {
	SIZE_T Detected;
	SIZE_T TotalScanned;
	SIZE_T Errors;
	FLOAT Clock;
	ULONG ScanSize;
	FLOAT ElapsedTime() { return (clock() - Clock)/CLOCKS_PER_SEC; };
	FLOAT AverageSizePerTime(){ return ScanSizeInMB() / ElapsedTime(); };
	FLOAT ScanSizeInMB(){return ScanSize / (1024.0*1024); };
```

```
       VOID Reset() { Clock = clock() ; ScanSize = 0; Detected = 0 ;  TotalScanned = 0 ;
Errors = 0; };
       ScanResult() : Clock(clock()) , ScanSize(0) , Detected(0) , TotalScanned(0) ,
Errors(0){};
};

/******************** Global Variables ********************/
ScanResult                 GlobalScanResult;
SignatureDatabase    GlobalSignatureDatabase;
queue<string> DirectoryQueue;
/**********************************************************/

VOID Log(LogCode Code, const string& Argument = ""){
       switch(Code){
       case LogCode::PRINT_FINAL_RESULTS:
              printf(" ----------------------------------------------------------------
\n");
              printf("|              # Scanned  Files   : %-10d  File(s)
|\n",GlobalScanResult.TotalScanned);
              printf("|              # Detected Files   : %-10d  File(s)
|\n",GlobalScanResult.Detected);
              printf("|              # Occured Errors   : %-10d  File(s)
|\n",GlobalScanResult.Errors);
              printf("|              # Elapsed Time     : %-10.4f  Second(s)
|\n",GlobalScanResult.ElapsedTime());
              printf("|              # Scan Size        : %-10.4f  MB
|\n",GlobalScanResult.ScanSizeInMB());
              printf("|              # Size/Time        : %-10.4f  MB/S
|\n",GlobalScanResult.AverageSizePerTime());
              printf(" ----------------------------------------------------------------
\n");
              break;
       case LogCode::READ_FILE_ERR:
              cout << "[-] Error While Reading File : \'" <<
strrchr(Argument.c_str(),'\\') + 1 << "'\n";
              break;
       case LogCode::DIR_NOT_FOUND:
              cout << "[-] Directory Not Found : \'" << Argument << "'\n";
              break;
       case LogCode::MEM_ALOC_FILE_ERR:
              cout << "[-] Error While Allocating Memory For File : \'" <<
strrchr(Argument.c_str(),'\\') + 1 << "'\n";
              break;
       case LogCode::OPEN_SIGN_FILE_ERR:
              cout << "[-] Error While Opening The Signature File.\n";
              break;
       case LogCode::MEM_ALOC_SIGN_FILE_ERR:
              cout << "[-] Error While Allocating Memory For The Signature File.\n";
              break;
       case LogCode::OPEN_FILE_ERR:
              cout << "[-] Error While Opening File : \'" <<
strrchr(Argument.c_str(),'\\') + 1 << "'\n";
              break;
       case LogCode::AFFECTED_FILE:
              cout << "[-] AFFECTED  : " << strrchr(Argument.c_str(),'\\') + 1 << "\n";
              break;
       case LogCode::CLEAN_FILE:
              cout << "[-] CLEAN     : " << strrchr(Argument.c_str(),'\\') + 1 << "\n";
```

```
			break;
		}
}

//	Converting a One Byte Hex String To Its Equivalent Integer Value.
INT OneByteAsciiHexToInt(CHAR *String){
	INT i=0,Value=0;
	while(String[i] != '\0'){
		if(String[i] >= 'A' && String[i] <= 'F'){
			Value += (String[i]-'A' + 10)*(pow((DOUBLE)16,(INT)1-i));
		}else if(String[i] >= 'a' && String[i] <= 'f'){
			Value += (String[i]-'a' + 10)*(pow((DOUBLE)16,(INT)1-i));
		}else{
			Value += (String[i]-'0')*(pow((DOUBLE)16,(INT)1-i));
		}
		i++;
	}
	return Value;
}

VOID ConsoleInitializer(VOID){
	SetConsoleTitle(L"Veronica Antivirus");
	cout << " ------------------------------------------------------------- \n";
	cout << "|                     Veronica Antivirus                      |\n";
	cout << "|                 Written By Ahmad Siavashi                   |\n";
	cout << "|                Email : a.siavosh@yahoo.com                  |\n";
	cout << "|                     Shiraz  University                      |\n";
	cout << "|                        Spring 2012                          |\n";
	cout << " ------------------------------------------------------------- \n";
}

//	String Matching Algorithm.
bool DetectSignatureInFile(File * pFile){
	for(int i=0;i<pFile->FileSize.QuadPart;i++){
		int j,k;
		if(pFile->pFile[i] == GlobalSignatureDatabase.pDatabase[0]){
			for(j=1,k=i+1;j < GlobalSignatureDatabase.DatabaseSize && k < pFile-
>FileSize.QuadPart;j++,k++){
				if(GlobalSignatureDatabase.pDatabase[j] != pFile->pFile[k])
					break;
			}
			if(j == GlobalSignatureDatabase.DatabaseSize){
				return true;
			}
		}
	}
	return false;
}

//	Obtaining The Signature File.
ReturnCode LoadSignature(string& SignatureFileName){
	INT i=0,j=0,c='\0',k=0;
	CHAR aChar[3];
	CHAR *pReadBuffer;
	DWORD dwBytesRead;
	LARGE_INTEGER FileSize;
	GlobalSignatureDatabase.Target = string(SignatureFileName);
	if((GlobalSignatureDatabase.hFile = 
CreateFileA(SignatureFileName.c_str(),GENERIC_READ,FILE_SHARE_READ,NULL,OPEN_EXISTING,FIL
E_ATTRIBUTE_NORMAL | FILE_FLAG_NO_BUFFERING | FILE_FLAG_WRITE_THROUGH ,NULL)) == 
INVALID_HANDLE_VALUE){
		Log(LogCode::OPEN_SIGN_FILE_ERR);
		system("PAUSE");
		exit(EXIT_FAILURE);
	}
	GetFileSizeEx(GlobalSignatureDatabase.hFile,&FileSize);
	GlobalSignatureDatabase.DatabaseSize = (FileSize.QuadPart+1)/3;
	if((GlobalSignatureDatabase.pDatabase = new (nothrow) 
BYTE[int(ceil((float)FileSize.QuadPart / 512)*512)])==nullptr){
		Log(LogCode::MEM_ALOC_SIGN_FILE_ERR);
		system("PAUSE");
		exit(EXIT_FAILURE);
	}
	pReadBuffer = new (nothrow) CHAR[FileSize.QuadPart];
	ReadFile(GlobalSignatureDatabase.hFile,pReadBuffer,ceil((float)FileSize.QuadPart / 
512)*512, &dwBytesRead,nullptr);
	while((c=pReadBuffer[k]) != '\n' && c!=EOF && k++ <= dwBytesRead){
		if(c != ' '){
			aChar[j++] = c;
			if(j==2){
				aChar[j] = '\0';
				GlobalSignatureDatabase.pDatabase[i] = 
OneByteAsciiHexToInt(aChar);
				j = 0;
				i++;
			}
		}
	}
	delete[] pReadBuffer;
	return ReturnCode::VAV_SUCCESS;
}

File * LoadFile(CONST CHAR *FileName){
	File * pFile = new File;
	pFile->Target = string(FileName);
	if((pFile->hFileStream = CreateFileA(pFile-
>Target.c_str(),GENERIC_READ,FILE_SHARE_READ,NULL,OPEN_EXISTING,FILE_ATTRIBUTE_NORMAL | 
FILE_FLAG_NO_BUFFERING | FILE_FLAG_WRITE_THROUGH,NULL))==INVALID_HANDLE_VALUE){
		Log(LogCode::OPEN_FILE_ERR,pFile->Target);
		delete pFile;
		return nullptr;
	}

	DWORD dwBytesRead;

	GetFileSizeEx(pFile->hFileStream,&pFile->FileSize);
	if((pFile->pFile = new BYTE[int(ceil((float)pFile->FileSize.QuadPart / 512)*512)]) 
== NULL){
		Log(LogCode::MEM_ALOC_FILE_ERR,pFile->Target);
		delete pFile;
		return nullptr;
	}

	if(ReadFile(pFile->hFileStream,pFile->pFile,ceil((float)pFile->FileSize.QuadPart / 
512)*512, &dwBytesRead,NULL) == 0){
```

```
            Log(LogCode::READ_FILE_ERR,pFile->Target);
            free(pFile->pFile);
            delete pFile;
            return nullptr;
        }
        return pFile;
}

bool QueueDirectoryFiles(CHAR * Dir){
        HANDLE                          hFindFile;
        WIN32_FIND_DATAA        Win32FindData;
        CHAR                            Directory[MAX_PATH];

        sprintf(Directory,"%s\\*.*",Dir);
        if((hFindFile=FindFirstFileA(Directory,&Win32FindData))==INVALID_HANDLE_VALUE){
                Log(LogCode::DIR_NOT_FOUND,Dir);
                return false;
        }

        do{
                if(strcmp(Win32FindData.cFileName,".") != 0 &&
strcmp(Win32FindData.cFileName,"..") != 0){
                        sprintf(Directory,"%s\\%s",Dir,Win32FindData.cFileName);
                        if(Win32FindData.dwFileAttributes & FILE_ATTRIBUTE_DIRECTORY){
                                QueueDirectoryFiles(Directory);
                        }else{
                                DirectoryQueue.push(string(Directory));
                        }
                }
        }while(FindNextFileA(hFindFile,&Win32FindData));
        FindClose(hFindFile);
        return TRUE;
}

VOID ScanFile(string FileName){
        File * pFile = nullptr;
        if((pFile = LoadFile((const char *)FileName.c_str())) != nullptr){
                if(DetectSignatureInFile(pFile)){
                        GlobalScanResult.Detected++;
                        Log(LogCode::AFFECTED_FILE,FileName);
                }else{
                        Log(LogCode::CLEAN_FILE,FileName);
                }
                GlobalScanResult.TotalScanned++;
                GlobalScanResult.ScanSize += pFile->FileSize.QuadPart;
                pFile->Release();
                delete pFile;

                CHAR ConsoleTitle[MAX_PATH];
                sprintf(ConsoleTitle,"VAV - %d File(s) Scanned : %d File(s) Detected - %d
Error(s)
Occurred\n",GlobalScanResult.TotalScanned,GlobalScanResult.Detected,GlobalScanResult.Erro
rs);
                SetConsoleTitleA(ConsoleTitle);
                /**/
        }else{
                GlobalScanResult.Errors++;
        }
        /**/

}

VOID Scan(string Directory){
        GlobalScanResult.Reset();
        QueueDirectoryFiles((char *)Directory.c_str());
        while(!DirectoryQueue.empty()){
                ScanFile(DirectoryQueue.front());
                DirectoryQueue.pop();
        }
}

INT main(){
        ConsoleInitializer();
        LoadSignature(string("signature.txt"));
        stringstream Args(" ");
        string Cmd,temp,Line,Directory("C:\\");
        cout << "For more information, type 'help'." << endl;
        do {
                cout << ">> ";
                getline(cin,Line);
                Args.clear();
                Args << Line;
                Cmd.erase();
                Args >> Cmd;

                if(Cmd == "exit"){
                        break;
                }else if(Cmd == "help"){
                        cout << "exit" << endl;
                        cout << "scan <dir>" << endl;
                }else if(Cmd == "scan"){
                        Args >> temp;
                        if(temp != "-"){
                                Directory = temp;
                        }
                        Scan(Directory);
                        Log(LogCode::PRINT_FINAL_RESULTS);
                }
        }while(true);
        GlobalSignatureDatabase.Release();
        return EXIT_SUCCESS;
}
```

WinC.c

Sequential implemented in pure C but using Win32 APIs

```
#include <stdio.h>
#include <stdlib.h>
```

```c
#include <string.h>
#include <math.h>
#include <Windows.h>
#include <time.h>

#define WRITE_LOG_FILE      FALSE
#define FLUSH_LOG_FILE      FALSE
#define NUM_COUNTERS 1

VOID Log(CHAR * Message, CONST CHAR * Argument);


typedef enum ErrorCode { VAV_FALUIRE, VAV_SUCCESS } RET_CODE;
typedef enum LogCode { INIT_LOG_FILE, END_LOG_FILE,
PRINT_FINAL_RESULTS,READ_FILE_ERR,DIR_NOT_FOUND,MEM_ALOC_FILE_ERR,OPEN_SIGN_FILE_ERR,MEM_
ALOC_SIGN_FILE_ERR,OPEN_FILE_ERR,AFFECTED_FILE,CLEAN_FILE } LOG_CODE;


typedef struct File {
       BYTE *pFile;
       LARGE_INTEGER FileSize;
       CHAR Target[MAX_PATH];
       HANDLE hFileStream;
} *VAV_File;

typedef struct SignatureDatabase {
       BYTE *pDatabase;
       DWORD DatabaseSize;
       CHAR Target[MAX_PATH];
       HANDLE hFile;
} *VAV_DB;

typedef struct ScanResult {
       SIZE_T Detected;
       SIZE_T TotalScanned;
       SIZE_T Errors;
} VAV_Result;

typedef struct Counter{
       clock_t       Clock;
       ULONG  ScanSize;
} VAV_Counter;

// Global Variables

FILE   *pLogFile;
VAV_Result    ScanResult;
VAV_Counter Counter[NUM_COUNTERS];

VOID ResetResults(VOID){
       ScanResult.Detected = 0;
       ScanResult.Errors = 0;
       ScanResult.TotalScanned = 0;
}

VOID AddSize(INT CounterId,ULONG Size){
       Counter[CounterId].ScanSize += Size;
}
```

```
DOUBLE ElapsedTime(INT CounterId){
	return ((DOUBLE)Counter[CounterId].Clock)/CLOCKS_PER_SEC;
}

DOUBLE TotalSizeInMB(INT CounterId){
	return ((DOUBLE)Counter[CounterId].ScanSize)/(1024*1024);
}

DOUBLE AverageSizePerTime(INT CounterId){
	return TotalSizeInMB(CounterId) / ElapsedTime(CounterId);
}

VOID SetStopWatch(INT CounterId){
	Counter[CounterId].Clock = clock();
}

VOID HoldStopWatch(INT CounterId){
	Counter[CounterId].Clock = clock() - Counter[CounterId].Clock;
}

VOID ResetStopWatch(INT CounterId){
	Counter[CounterId].Clock = 0;
}

VOID ResetSizeCounter(INT CounterId){
	Counter[CounterId].ScanSize = 0;
}

VOID ResetCounter(INT CounterId){
	Counter[CounterId].Clock = 0;
	Counter[CounterId].ScanSize = 0;
}

//	Converting a One Byte Hex String To Its Equivalent Integer Value.
INT OneByteAsciiHexToInt(CHAR *String){
	INT i=0,Value=0;
	while(String[i] != '\0'){
		if(String[i] >= 'A' && String[i] <= 'F'){
			Value += (String[i]-'A' + 10)*(pow((DOUBLE)16,(INT)1-i));
		}else if(String[i] >= 'a' && String[i] <= 'f'){
			Value += (String[i]-'a' + 10)*(pow((DOUBLE)16,(INT)1-i));
		}else{
			Value += (String[i]-'0')*(pow((DOUBLE)16,(INT)1-i));
		}
		i++;
	}
	return Value;
}

//	String Matching Algorithm.
BOOL DetectSignatureInFile(VAV_File File,VAV_DB Signature){
	UINT i=0,j=0,k=0;
	for(i=0;i<File->FileSize.QuadPart;i++){
		if(File->pFile[i] == Signature->pDatabase[0]){
			for(j=1,k=i+1;j < Signature->DatabaseSize && k < File-
>FileSize.QuadPart;j++,k++){
				if(Signature->pDatabase[j] != File->pFile[k])
```

```
                                        break;
                                }
                                if(j == Signature->DatabaseSize){
                                        return TRUE;
                                }
                        }
                }
                return FALSE;
}

//      Obtaining The Signature File.
RET_CODE LoadSignature(CONST CHAR * SignatureFileName, VAV_DB *pSignature){
        INT i=0,j=0,c='\0',k=0;
        CHAR aChar[3];
        CHAR *pReadBuffer;
        DWORD dwBytesRead;
        LARGE_INTEGER FileSize;
        *pSignature = (VAV_DB) malloc(sizeof(struct SignatureDatabase));
        strcpy((*pSignature)->Target,SignatureFileName);
        if(((*pSignature)->hFile =
CreateFileA(SignatureFileName,GENERIC_READ,FILE_SHARE_READ,NULL,OPEN_EXISTING,FILE_ATTRIB
UTE_NORMAL | FILE_FLAG_NO_BUFFERING | FILE_FLAG_WRITE_THROUGH ,NULL)) ==
INVALID_HANDLE_VALUE){
                Log(OPEN_SIGN_FILE_ERR,NULL);
                system("PAUSE");
                exit(EXIT_FAILURE);
        }
        GetFileSizeEx((*pSignature)->hFile,&FileSize);
        (*pSignature)->DatabaseSize = (FileSize.QuadPart+1)/3;
        if(((*pSignature)->pDatabase = (BYTE *)
malloc(sizeof(BYTE)*(ceil((float)FileSize.QuadPart / 512)*512)))==NULL){
                Log(MEM_ALOC_SIGN_FILE_ERR,NULL);
                system("PAUSE");
                exit(EXIT_FAILURE);
        }
        pReadBuffer = (CHAR *) malloc(sizeof(CHAR)*FileSize.QuadPart);
        ReadFile((*pSignature)->hFile,pReadBuffer,ceil((float)FileSize.QuadPart /
512)*512, &dwBytesRead,NULL);
        while((c=pReadBuffer[k]) != '\n' && c!=EOF && k++ <= dwBytesRead){
                if(c != ' '){
                        aChar[j++] = c;
                        if(j==2){
                                aChar[j] = '\0';
                                (*pSignature)->pDatabase[i] = OneByteAsciiHexToInt(aChar);
                                j = 0;
                                i++;
                        }
                }
        }
        free(pReadBuffer);
        return VAV_SUCCESS;
}

RET_CODE GetFile(CONST CHAR *FileName, VAV_File *pFile){
        *pFile = (VAV_File) malloc(sizeof(struct File));
        if(((*pFile)->hFileStream =
CreateFileA(FileName,GENERIC_READ,FILE_SHARE_READ,NULL,OPEN_EXISTING,FILE_ATTRIBUTE_NORMA
L | FILE_FLAG_NO_BUFFERING | FILE_FLAG_WRITE_THROUGH,NULL))==INVALID_HANDLE_VALUE){
```

```
              Log(OPEN_FILE_ERR,FileName);
              free(*pFile);
              *pFile = NULL;
              return VAV_FALUIRE;
       }
       strcpy((*pFile)->Target,FileName);
       return VAV_SUCCESS;
}


DWORD LoadFile(VAV_File File){
       DWORD dwBytesRead;
       GetFileSizeEx(File->hFileStream,&File->FileSize);
       if((File->pFile = (BYTE *) malloc(sizeof(BYTE) * (ceil((float)File-
>FileSize.QuadPart / 512)*512))) == NULL){
              Log(MEM_ALOC_FILE_ERR,File->Target);
              return VAV_FALUIRE;
       }

       if(ReadFile(File->hFileStream,File->pFile,ceil((float)File->FileSize.QuadPart /
512)*512, &dwBytesRead,NULL) == 0){
              Log(READ_FILE_ERR,File->Target);
              free(File->pFile);
              return VAV_FALUIRE;
       }
       return VAV_SUCCESS;
}

RET_CODE ReleaseFile(VAV_File *pFile){
       free((*pFile)->pFile);
       CloseHandle((*pFile)->hFileStream);
       free((*pFile));
       *pFile = NULL;
       return VAV_SUCCESS;
}

RET_CODE ReleaseDatabase(VAV_DB *pDatabase){
       free((*pDatabase)->pDatabase);
       CloseHandle((*pDatabase)->hFile);
       free((*pDatabase));
       *pDatabase = NULL;
       return VAV_SUCCESS;
}

BOOL ScanDirectoryFiles(CONST CHAR *Dir,VAV_DB Signature,INT CounterId){
       HANDLE                     hFindFile;
       WIN32_FIND_DATAA    Win32FindData;
       CHAR                       Directory[MAX_PATH];
       VAV_File                   File = NULL;
       CHAR                       ConsoleTitle[MAX_PATH];
       sprintf(Directory,"%s\\*.*",Dir);
       if((hFindFile=FindFirstFileA(Directory,&Win32FindData))==INVALID_HANDLE_VALUE){
              Log(DIR_NOT_FOUND,Dir);
              return FALSE;
       }
       do{
              if(strcmp(Win32FindData.cFileName,".") != 0 &&
strcmp(Win32FindData.cFileName,"..") != 0){
```

```
                        sprintf(Directory,"%s\\%s",Dir,Win32FindData.cFileName);
                        if(Win32FindData.dwFileAttributes & FILE_ATTRIBUTE_DIRECTORY){
                                ScanDirectoryFiles(Directory,Signature,CounterId);
                        }else{
                                if(GetFile(Directory,&File) != VAV_FALUIRE)
                                        if(LoadFile(File) == VAV_FALUIRE)
                                                ReleaseFile(&File);
                                if(File != NULL){
                                        if(DetectSignatureInFile(File,Signature)==TRUE){
                                                ScanResult.Detected++;
                                                Log(AFFECTED_FILE,Directory);
                                        }else{
                                                Log(CLEAN_FILE,Directory);
                                        }
                                        ScanResult.TotalScanned++;
                                        AddSize(CounterId,File->FileSize.QuadPart);
                                        ReleaseFile(&File);
                                        sprintf(ConsoleTitle,"VAV - %d File(s) Scanned : %d
File(s) Detected - %d Error(s)
Occurred\n",ScanResult.TotalScanned,ScanResult.Detected,ScanResult.Errors);
                                        SetConsoleTitleA(ConsoleTitle);
                                }else{
                                        ScanResult.Errors++;
                                }
                        }
                }
        }while(FindNextFileA(hFindFile,&Win32FindData));
        FindClose(hFindFile);
        return TRUE;
}

INT GetLine(CHAR Line[],INT MaxLen){
        UINT i = 0;
        INT     c = '\0';
        while((c=getchar())!='\n' && i < MaxLen)
                Line[i++] = c;
        Line[i] = '\0';
        return i;
}

VOID ConsoleInitializer(VOID){
        SetConsoleTitle(L"Veronica Antivirus");
        printf(" ------------------------------------------------------------- \n");
        printf("|                       Veronica Antivirus                     |\n");
        printf("|                   Written By Ahmad Siavashi                  |\n");
        printf("|                  Email : a.siavosh@yahoo.com                 |\n");
        printf("|                       Shiraz  University                     |\n");
        printf("|                          Spring 2012                         |\n");
        printf(" ------------------------------------------------------------- \n");
}

VOID Log(LOG_CODE Code, CONST CHAR * Argument){
        switch(Code){
        case INIT_LOG_FILE:
                if(WRITE_LOG_FILE)pLogFile = fopen("log.txt","w");
                break;
        case PRINT_FINAL_RESULTS:
                printf(" -----------------------------------------------------------------
\n");
                printf("|               # Scanned  Files   : %-10d File(s)
|\n",ScanResult.TotalScanned);
                printf("|               # Detected Files   : %-10d File(s)
|\n",ScanResult.Detected);
                printf("|               # Occured Errors   : %-10d File(s)
|\n",ScanResult.Errors);
                printf("|               # Elapsed Time(%d)  : %-10lf Second(s)
|\n",(INT)Argument,ElapsedTime((INT)Argument));
                printf("|               # Scan Size(%d)     : %-10lf MB
|\n",(INT)Argument,TotalSizeInMB((INT)Argument));
                printf("|               # Size/Time(%d)     : %-10lf MB/S
|\n",(INT)Argument,AverageSizePerTime((INT)Argument));
                printf(" -----------------------------------------------------------------
\n");
                if(WRITE_LOG_FILE){
                        fprintf(pLogFile,"[-] %d File(s) Scanned : %d File(s) Detected, %d
Error(s) Occurred.\n",ScanResult.TotalScanned,ScanResult.Detected,ScanResult.Errors);
                        fprintf(pLogFile,"[-] Elapsed Time : %lf Second(s)
\n",ElapsedTime((INT)Argument));
                }
                break;
        case READ_FILE_ERR:
                printf("[-] Error While Reading File : \'%s\'\n",strrchr(Argument,'\\')+1);
                if(WRITE_LOG_FILE) fprintf(pLogFile,"[-] Error While Reading File :
\'%s\'\n",Argument);
                break;
        case DIR_NOT_FOUND:
                printf("[-] Directory Not Found : \'%s\'\n",Argument);
                break;
        case MEM_ALOC_FILE_ERR:
                printf("[-] Error While Allocating Memory For File :
\'%s\'\n",strrchr(Argument,'\\')+1);
                if(WRITE_LOG_FILE) fprintf(pLogFile,"[-] Error While Allocating Memory For
File : \'%s\'\n", Argument);
                break;
        case OPEN_SIGN_FILE_ERR:
                printf("[-] Error While Opening The Signature File.\n");
                break;
        case MEM_ALOC_SIGN_FILE_ERR:
                printf("[-] Error While Allocating Memory For The Signature File.\n");
                break;
        case OPEN_FILE_ERR:
                printf("[-] Error While Opening File : \'%s\'\n",strrchr(Argument,'\\')+1);
                if(WRITE_LOG_FILE) fprintf(pLogFile,"[-] Error While Opening File :
\'%s\'\n",Argument);
                break;
        case AFFECTED_FILE:
                printf("[-] AFFECTED  : %s\n",strrchr(Argument,'\\')+1);
                if(WRITE_LOG_FILE) fprintf(pLogFile,"[-] AFFECTED  : %s\n",Argument);
                break;
        case CLEAN_FILE:
                printf("[-] CLEAN     : %s\n",strrchr(Argument,'\\')+1);
                if(WRITE_LOG_FILE) fprintf(pLogFile,"[-] CLEAN     : %s\n",Argument);
                break;
        case END_LOG_FILE:
                fflush(pLogFile);
```

```c
			fclose(pLogFile);
			break;
		}
		if(FLUSH_LOG_FILE) fflush(pLogFile);
}

INT main(){
		VAV_DB Signature = NULL;
		CHAR   Path[MAX_PATH] = "";
		ConsoleInitializer();
GET_DIR:
		printf(">>> Directory Address : ");
		if(!GetLine(Path,MAX_PATH))
			goto GET_DIR;
		LoadSignature("signature.txt",&Signature);
		Log(INIT_LOG_FILE,NULL);
START_SCAN:
		ResetResults();
		ResetCounter(0);
		SetStopWatch(0);
		ScanDirectoryFiles(Path,Signature,0);
		HoldStopWatch(0);
		Log(PRINT_FINAL_RESULTS,0);
AGAIN:
		{
			CHAR TemporaryPath[MAX_PATH];
			printf(">>> Directory Address [ '-' For Previous Directory ] : ");
			if(!GetLine(TemporaryPath,MAX_PATH))
				goto AGAIN;
			if(!strcmp(TemporaryPath,"-"))
				goto START_SCAN;
			strcpy(Path,TemporaryPath);
			goto START_SCAN;
		}
END:
		ReleaseDatabase(&Signature);
		Log(END_LOG_FILE,NULL);
		return EXIT_SUCCESS;
}
```

PlainC.c

Sequential Implementation in Pure C

```c
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <math.h>
#include <Windows.h>
#include <time.h>
```

```
#define WRITE_LOG_FILE      TRUE
#define FLUSH_LOG_FILE      TRUE
#define NUM_COUNTERS 1

VOID Log(CHAR * Message, CONST CHAR * Argument);


typedef enum ErrorCode { VAV_SUCCESS, VAV_FALUIRE } RET_CODE;
typedef enum LogCode { INIT_LOG_FILE, END_LOG_FILE,
PRINT_FINAL_RESULTS,READ_FILE_ERR,DIR_NOT_FOUND,MEM_ALOC_FILE_ERR,OPEN_SIGN_FILE_ERR,MEM_
ALOC_SIGN_FILE_ERR,OPEN_FILE_ERR,AFFECTED_FILE,CLEAN_FILE } LOG_CODE;


typedef struct File {
       BYTE *pFile;
       SIZE_T FileSize;
       CHAR Target[MAX_PATH];
       FILE *pFileStream;
} *VAV_File;

typedef struct SignatureDatabase {
       BYTE *pDatabase;
       SIZE_T DatabaseSize;
       CHAR Target[MAX_PATH];
       FILE *pFileStream;
} *VAV_DB;

typedef struct ScanResult {
       SIZE_T Detected;
       SIZE_T TotalScanned;
       SIZE_T Errors;
} VAV_Result;

typedef struct Counter{
       clock_t       Clock;
       ULONG  ScanSize;
} VAV_Counter;

// Global Variables

FILE   *pLogFile;
VAV_Result    ScanResult;
VAV_Counter Counter[NUM_COUNTERS];

VOID ResetResults(VOID){
       ScanResult.Detected = 0;
       ScanResult.Errors = 0;
       ScanResult.TotalScanned = 0;
}

VOID AddSize(INT CounterId,ULONG Size){
       Counter[CounterId].ScanSize += Size;
}

DOUBLE ElapsedTime(INT CounterId){
       return ((DOUBLE)Counter[CounterId].Clock)/CLOCKS_PER_SEC;
}
```

```
DOUBLE TotalSizeInMB(INT CounterId){
	return ((DOUBLE)Counter[CounterId].ScanSize)/(1024*1024);
}

DOUBLE AverageSizePerTime(INT CounterId){
	return TotalSizeInMB(CounterId) / ElapsedTime(CounterId);
}

VOID SetStopWatch(INT CounterId){
	Counter[CounterId].Clock = clock();
}

VOID HoldStopWatch(INT CounterId){
	Counter[CounterId].Clock = clock() - Counter[CounterId].Clock;
}

VOID ResetStopWatch(INT CounterId){
	Counter[CounterId].Clock = 0;
}

VOID ResetSizeCounter(INT CounterId){
	Counter[CounterId].ScanSize = 0;
}

VOID ResetCounter(INT CounterId){
	Counter[CounterId].Clock = 0;
	Counter[CounterId].ScanSize = 0;
}

//	Converting a One Byte Hex String To Its Equivalent Integer Value.
INT OneByteAsciiHexToInt(CHAR *String){
	INT i=0,Value=0;
	while(String[i] != '\0'){
		if(String[i] >= 'A' && String[i] <= 'F'){
			Value += (String[i]-'A' + 10)*(pow((DOUBLE)16,(INT)1-i));
		}else if(String[i] >= 'a' && String[i] <= 'f'){
			Value += (String[i]-'a' + 10)*(pow((DOUBLE)16,(INT)1-i));
		}else{
			Value += (String[i]-'0')*(pow((DOUBLE)16,(INT)1-i));
		}
		i++;
	}
	return Value;
}

//	String Matching Algorithm.
BOOL DetectSignatureInFile(VAV_File File,VAV_DB Signature){
	UINT i=0,j=0,k=0;
	for(i=0;i<File->FileSize;i++){
		if(File->pFile[i] == Signature->pDatabase[0]){
			for(j=1,k=i+1;j < Signature->DatabaseSize && k < File-
>FileSize;j++,k++){
				if(Signature->pDatabase[j] != File->pFile[k])
					break;
			}
			if(j == Signature->DatabaseSize){
				return TRUE;
			}
			}
		}
		return FALSE;
}

//	Obtaining The Signature File.
RET_CODE LoadSignature(CONST CHAR * SignatureFileName, VAV_DB *pSignature){
		INT i=0,j=0,c='\0';
		CHAR aChar[3];
		*pSignature = (VAV_DB) malloc(sizeof(struct SignatureDatabase));
		strcpy((*pSignature)->Target,SignatureFileName);
		if(((*pSignature)->pFileStream = fopen(SignatureFileName,"r"))==NULL){
			Log(OPEN_SIGN_FILE_ERR,NULL);
			system("PAUSE");
			exit(EXIT_FAILURE);
		}
		fseek((*pSignature)->pFileStream,0,SEEK_END);
		(*pSignature)->DatabaseSize = (ftell((*pSignature)->pFileStream)+1)/3;
		rewind((*pSignature)->pFileStream);
		if(((*pSignature)->pDatabase = (BYTE *) malloc(sizeof(BYTE)*(*pSignature)-
>DatabaseSize))==NULL){
			Log(MEM_ALOC_SIGN_FILE_ERR,NULL);
			system("PAUSE");
			exit(EXIT_FAILURE);
		}
		rewind((*pSignature)->pFileStream);
		while((c=fgetc((*pSignature)->pFileStream)) != '\n' && c!=EOF){
			if(c != ' '){
				aChar[j++] = c;
				if(j==2){
					aChar[j] = '\0';
					(*pSignature)->pDatabase[i] = OneByteAsciiHexToInt(aChar);
					j = 0;
					i++;
				}
			}
		}
		return VAV_SUCCESS;
}

RET_CODE GetFile(CONST CHAR *FileName, VAV_File *pFile){
		*pFile = (VAV_File) malloc(sizeof(struct File));
		if(((*pFile)->pFileStream = fopen(FileName,"rb"))==NULL){
			Log(OPEN_FILE_ERR,FileName);
			free(*pFile);
			*pFile = NULL;
			return VAV_FALUIRE;
		}
		strcpy((*pFile)->Target,FileName);
		return VAV_SUCCESS;
}


RET_CODE LoadFile(VAV_File File){
		fseek(File->pFileStream, 0, SEEK_END);
		File->FileSize = ftell(File->pFileStream);
		rewind(File->pFileStream);
```

```
        if((File->pFile = (BYTE *) malloc(sizeof(BYTE) * File->FileSize )) == NULL){
                Log(MEM_ALOC_FILE_ERR,File->Target);
                free(File->pFile);
                return VAV_FALUIRE;
        }

        if(fread(File->pFile,File->FileSize,1,File->pFileStream) == 0){
                Log(READ_FILE_ERR,File->Target);

                return VAV_FALUIRE;
        }
        return VAV_SUCCESS;
}

RET_CODE ReleaseFile(VAV_File *pFile){
        free((*pFile)->pFile);
        fclose((*pFile)->pFileStream);
        free((*pFile));
        *pFile = NULL;
        return VAV_SUCCESS;
}

RET_CODE ReleaseDatabase(VAV_DB *pDatabase){
        free((*pDatabase)->pDatabase);
        fclose((*pDatabase)->pFileStream);
        free((*pDatabase));
        *pDatabase = NULL;
        return VAV_SUCCESS;
}

BOOL ScanDirectoryFiles(CONST CHAR *Dir,VAV_DB Signature,INT CounterId){
        HANDLE                          hFindFile;
        WIN32_FIND_DATAA        Win32FindData;
        CHAR                            Directory[MAX_PATH];
        VAV_File                        File = NULL;
        CHAR                            ConsoleTitle[MAX_PATH];
        sprintf(Directory,"%s\\*.*",Dir);
        if((hFindFile=FindFirstFileA(Directory,&Win32FindData))==INVALID_HANDLE_VALUE){
                Log(DIR_NOT_FOUND,Dir);
                return FALSE;
        }
        do{
                if(strcmp(Win32FindData.cFileName,".") != 0 &&
strcmp(Win32FindData.cFileName,"..") != 0){
                        sprintf(Directory,"%s\\%s",Dir,Win32FindData.cFileName);
                        if(Win32FindData.dwFileAttributes & FILE_ATTRIBUTE_DIRECTORY){
                                ScanDirectoryFiles(Directory,Signature,CounterId);
                        }else{
                                if(GetFile(Directory,&File) == VAV_SUCCESS)
                                        if(LoadFile(File)!=VAV_SUCCESS)
                                                ReleaseFile(&File);
                                if(File != NULL){
                                        if(DetectSignatureInFile(File,Signature)==TRUE){
                                                ScanResult.Detected++;
                                                Log(AFFECTED_FILE,Directory);
                                        }else{
                                                Log(CLEAN_FILE,Directory);
                                        }
```

```
                                    ScanResult.TotalScanned++;
                                    AddSize(CounterId,File->FileSize);
                                    ReleaseFile(&File);
                                    sprintf(ConsoleTitle,"VAV - %d File(s) Scanned : %d
File(s) Detected - %d Error(s)
Occurred\n",ScanResult.TotalScanned,ScanResult.Detected,ScanResult.Errors);
                                    SetConsoleTitleA(ConsoleTitle);
                             }else{
                                    ScanResult.Errors++;
                             }
                      }
               }
       }while(FindNextFileA(hFindFile,&Win32FindData));
       FindClose(hFindFile);
       return TRUE;
}

INT GetLine(CHAR Line[],INT MaxLen){
       UINT i = 0;
       INT    c = '\0';
       while((c=getchar())!='\n' && i < MaxLen)
              Line[i++] = c;
       Line[i] = '\0';
       return i;
}

VOID ConsoleInitializer(VOID){
       SetConsoleTitle(L"Veronica Antivirus");
       printf(" -------------------------------------------------------------- \n");
       printf("|                      Veronica Antivirus                      |\n");
       printf("|                  Written By Ahmad Siavashi                   |\n");
       printf("|                 Email : a.siavosh@yahoo.com                  |\n");
       printf("|                      Shiraz  University                      |\n");
       printf("|                         Spring 2012                          |\n");
       printf(" -------------------------------------------------------------- \n");
}

VOID Log(LOG_CODE Code, CONST CHAR * Argument){
       switch(Code){
       case INIT_LOG_FILE:
              if(WRITE_LOG_FILE)pLogFile = fopen("log.txt","w");
              break;
       case PRINT_FINAL_RESULTS:
              printf(" -----------------------------------------------------------------
\n");
              printf("|              # Scanned  Files   : %-10d File(s)
|\n",ScanResult.TotalScanned);
              printf("|              # Detected Files   : %-10d File(s)
|\n",ScanResult.Detected);
              printf("|              # Occured Errors   : %-10d File(s)
|\n",ScanResult.Errors);
              printf("|              # Elapsed Time(%d)  : %-10lf Second(s)
|\n",(INT)Argument,ElapsedTime((INT)Argument));
              printf("|              # Scan Size(%d)     : %-10lf MB
|\n",(INT)Argument,TotalSizeInMB((INT)Argument));
              printf("|              # Size/Time(%d)     : %-10lf MB/S
|\n",(INT)Argument,AverageSizePerTime((INT)Argument));
```

```
              printf(" ---------------------------------------------------------------
\n");
              if(WRITE_LOG_FILE){
                     fprintf(pLogFile,"[-] %d File(s) Scanned : %d File(s) Detected, %d
Error(s) Occurred.\n",ScanResult.TotalScanned,ScanResult.Detected,ScanResult.Errors);
                     fprintf(pLogFile,"[-] Elapsed Time : %lf Second(s)
\n",ElapsedTime((INT)Argument));
              }
              break;
       case READ_FILE_ERR:
              printf("[-] Error While Reading File : \'%s\'\n",strrchr(Argument,'\\')+1);
              if(WRITE_LOG_FILE) fprintf(pLogFile,"[-] Error While Reading File :
\'%s\'\n",Argument);
              break;
       case DIR_NOT_FOUND:
              printf("[-] Directory Not Found : \'%s\'\n",Argument);
              break;
       case MEM_ALOC_FILE_ERR:
              printf("[-] Error While Allocating Memory For File :
\'%s\'\n",strrchr(Argument,'\\')+1);
              if(WRITE_LOG_FILE) fprintf(pLogFile,"[-] Error While Allocating Memory For
File : \'%s\'\n", Argument);
              break;
       case OPEN_SIGN_FILE_ERR:
              printf("[-] Error While Opening The Signature File.\n");
              break;
       case MEM_ALOC_SIGN_FILE_ERR:
              printf("[-] Error While Allocating Memory For The Signature File.\n");
              break;
       case OPEN_FILE_ERR:
              printf("[-] Error While Opening File : \'%s\'\n",strrchr(Argument,'\\')+1);
              if(WRITE_LOG_FILE) fprintf(pLogFile,"[-] Error While Opening File :
\'%s\'\n",Argument);
              break;
       case AFFECTED_FILE:
              printf("[-] AFFECTED  : %s\n",strrchr(Argument,'\\')+1);
              if(WRITE_LOG_FILE) fprintf(pLogFile,"[-] AFFECTED  : %s\n",Argument);
              break;
       case CLEAN_FILE:
              printf("[-] CLEAN     : %s\n",strrchr(Argument,'\\')+1);
              if(WRITE_LOG_FILE) fprintf(pLogFile,"[-] CLEAN     : %s\n",Argument);
              break;
       case END_LOG_FILE:
              fflush(pLogFile);
              fclose(pLogFile);
              break;
       }
       if(FLUSH_LOG_FILE) fflush(pLogFile);
}

INT main(){
       VAV_DB Signature = NULL;
       CHAR   Path[MAX_PATH] = "";
       ConsoleInitializer();
GET_DIR:
       printf(">>> Directory Address : ");
       if(!GetLine(Path,MAX_PATH))
              goto GET_DIR;
```

```
	LoadSignature("signature.txt",&Signature);
	Log(INIT_LOG_FILE,NULL);
START_SCAN:
	ResetResults();
	ResetCounter(0);
	SetStopWatch(0);
	ScanDirectoryFiles(Path,Signature,0);
	HoldStopWatch(0);
	Log(PRINT_FINAL_RESULTS,0);
AGAIN:
	{
		CHAR TemporaryPath[MAX_PATH];
		printf(">>> Directory Address [ '-' For Previous Directory ] : ");
		if(!GetLine(TemporaryPath,MAX_PATH))
			goto AGAIN;
		if(!strcmp(TemporaryPath,"-"))
			goto START_SCAN;
		strcpy(Path,TemporaryPath);
		goto START_SCAN;
	}
END:
	ReleaseDatabase(&Signature);
	Log(END_LOG_FILE,NULL);
	return EXIT_SUCCESS;
}
```