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## CSTRING CONCATENATION

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14. ABSTRACT  Concatenating two or more strings together while developing a C++ application is a very common task. For CStrings, there are two primary ways to concatenate strings. The first is to use the += operator to concatenate two strings, and the second is to use the + operator. This report compares the two operations.					
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CONTENTS

	Page
Introduction	1
Methodology	1
Conclusions	6
References	7
Distribution List	9



## INTRODUCTION

Concatenating two or more strings together while developing a C++ application is a very common task. CStrings provide two operators for concatenating strings. The first method is to use the += operator, and the second is to use the + operator. This report will analyze and compare the two operations.

In another report on appending std::strings together, it was found that it was more efficient to use the += operator instead of the + operator (ref. 1). This then led to the question of whether the CString class operated the same. It turns out that the CString performs about the same for both operators when only dealing with about 3 to 4 strings. Once there are more strings, then the += operator starts to outperform the + operator.

## METHODOLOGY

In order to acquire data for this report, the following program was written, which would concatenate a certain number of strings using the += operator and also concatenate the same strings using the + operator. I collected data for concatenating 2 to 10 strings. The source code for this program is shown on the following pages:

```
int _tmain(int argc, TCHAR* argv[], TCHAR* envp[])
{
    int nRetCode = 0;

    HMODULE hModule = ::GetModuleHandle(NULL);

    if(hModule != NULL)
    {
        // initialize MFC and print and error on failure
        if(!AfxWinInit(hModule, NULL, ::GetCommandLine(), 0))
        {
            // TODO: change error code to suit your needs
            _tprintf(_T("Fatal Error: MFC initialization failed\n"));
            nRetCode = 1;
        }
        else
        {
            LARGE_INTEGER frequency;
            QueryPerformanceFrequency(&frequency);

            LARGE_INTEGER starting_time, ending_time, elapsed_microseconds;

            //std::ofstream a_file("outfile2.txt");
            //std::ofstream a_file("outfile3.txt");
            //std::ofstream a_file("outfile4.txt");
            //std::ofstream a_file("outfile5.txt");
            //std::ofstream a_file("outfile6.txt");
            //std::ofstream a_file("outfile7.txt");
            //std::ofstream a_file("outfile8.txt");
            //std::ofstream a_file("outfile9.txt");
            std::ofstream a_file("outfile9.txt");
```

```

//setup strings here
std::vector<CString> my_strings;
my_strings.push_back(_T("This is the first."));
my_strings.push_back(_T("This is the second."));
my_strings.push_back(_T("This is the third."));
my_strings.push_back(_T("This is the fourth."));
my_strings.push_back(_T("This is the fifth."));
my_strings.push_back(_T("This is the sixth."));
my_strings.push_back(_T("This is the seventh."));
my_strings.push_back(_T("This is the eighth."));
my_strings.push_back(_T("This is the ninth."));
my_strings.push_back(_T("This is the tenth."));

CString plus_equal;
CString plus_plus;

for(auto i = 0u; i < 10; ++i)
{
    plus_equal = _T("");
    QueryPerformanceCounter(&starting_time);

    //code to measure here
    plus_equal = my_strings[0];
    plus_equal += my_strings[1];
    plus_equal += my_strings[2];
    plus_equal += my_strings[3];
    plus_equal += my_strings[4];
    plus_equal += my_strings[5];
    plus_equal += my_strings[6];
    plus_equal += my_strings[7];
    plus_equal += my_strings[8];
    plus_equal += my_strings[9];

    QueryPerformanceCounter(&ending_time);
    elapsed_microseconds.QuadPart = ending_time.QuadPart - starting_time.QuadPart;

    //this time is in micro seconds
    auto te_plus_equal = static_cast<double>((elapsed_microseconds.QuadPart *
1000000.0) / frequency.QuadPart);

    plus_plus = _T("");
    QueryPerformanceCounter(&starting_time);

    //code to measure here
    //plus_plus = my_strings[0] + my_strings[1];
    //plus_plus = my_strings[0] + my_strings[1] + my_strings[2];
    //plus_plus = my_strings[0] + my_strings[1] + my_strings[2] + my_strings[3];
    //plus_plus = my_strings[0] + my_strings[1] + my_strings[2] + my_strings[3] +
my_strings[4];
    //plus_plus = my_strings[0] + my_strings[1] + my_strings[2] + my_strings[3] +
my_strings[4] + my_strings[5];

```



```

        //plus_plus = my_strings[0] + my_strings[1] + my_strings[2] + my_strings[3] +
my_strings[4] + my_strings[5] + my_strings[6];
        //plus_plus = my_strings[0] + my_strings[1] + my_strings[2] + my_strings[3] +
my_strings[4] + my_strings[5] + my_strings[6] + my_strings[7];
        //plus_plus = my_strings[0] + my_strings[1] + my_strings[2] + my_strings[3] +
my_strings[4] + my_strings[5] + my_strings[6] + my_strings[7] + my_strings[8];
        plus_plus = my_strings[0] + my_strings[1] + my_strings[2] + my_strings[3] +
my_strings[4] + my_strings[5] + my_strings[6] + my_strings[7] + my_strings[8] +
my_strings[9];

        QueryPerformanceCounter(&ending_time);
        elapsed_microseconds.QuadPart = ending_time.QuadPart - starting_time.QuadPart;

        //this time is in micro seconds
        auto te_plus_plus = static_cast<double>((elapsed_microseconds.QuadPart *
1000000.0) / frequency.QuadPart);

        a_file << te_plus_equal << "," << te_plus_plus << "\r\n";

        printf("Run: %d \\\tte plus equal: %4.2f \\\tte plus plus: %4.2f\r\n", i + 1, te_plus_equal,
te_plus_plus);
    }

    a_file.close();

    printf("All done!\n");

    //this stops the program in order to see data;
    getchar();
}
else
{
    // TODO: change error code to suit your needs
    _tprintf(_T("Fatal Error: GetModuleHandle failed\n"));
    nRetCode = 1;
}

return nRetCode;
}

```

The code is very straightforward. Sections need to be commented out depending on the results that are desired. The built in high resolution counters are used in order to measure how long the concatenation took. The results are logged to the output file for later processing.

After running this program for each of the results desired, the results are shown in figure 1.

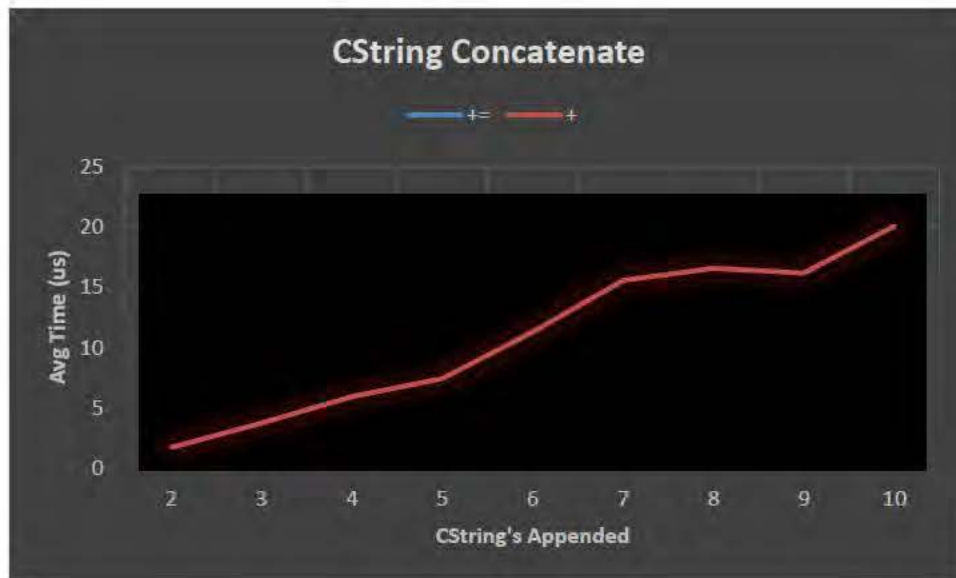


Figure 1  
CString concatenate

Figure 1 shows that for only a few CStrings, there was a negligible effect on performance. Once there was about four CStrings, there was a noticeable difference starting to emerge. As with the `std::string`, one would tend to use the `+=` instead of the `+` operator.

Let's take a look at the compiler generated assembly code in order to get a better idea why the measured results were received. For appending three CStrings, the assembly code is as follows:

```
plus_equal = my_strings[0];
00EEE006 push    0
00EEE008 lea     ecx,[ebp-128h]
00EEE00E call
std::vector<ATL::CStringT<wchar_t,StrTraitMFC_DLL<wchar_t,ATL::ChTraitsCRT<wchar_t>> >
>,std::allocator<ATL::CStringT<wchar_t,StrTraitMFC_DLL<wchar_t,ATL::ChTraitsCRT<wchar_t>> >
> >::operator[] (0EE1258h)
00EEE013 mov     esi,esp
00EEE015 push    eax
00EEE016 lea     ecx,[ebp-134h]
00EEE01C call    dword ptr ds:[0F0541Ch]
00EEE022 cmp     esi,esp
00EEE024 call    __RTC_CheckEsp (0EE1843h)
    plus_equal += my_strings[1];
00EEE029 push    1
00EEE02B lea     ecx,[ebp-128h]
00EEE031 call
std::vector<ATL::CStringT<wchar_t,StrTraitMFC_DLL<wchar_t,ATL::ChTraitsCRT<wchar_t>> >
>,std::allocator<ATL::CStringT<wchar_t,StrTraitMFC_DLL<wchar_t,ATL::ChTraitsCRT<wchar_t>> >
> >::operator[] (0EE1258h)
00EEE036 mov     esi,esp
00EEE038 push    eax
00EEE039 lea     ecx,[ebp-134h]
00EEE03F call    dword ptr ds:[0F05420h]
```

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```

00EEE045 cmp     esi,esp
00EEE047 call    __RTC_CheckEsp (0EE1843h)
           plus_equal += my_strings[2];
00EEE04C push    2
00EEE04E lea     ecx,[ebp-128h]
00EEE054 call
std::vector<ATL::CStringT<wchar_t,StrTraitMFC_DLL<wchar_t,ATL::ChTraitsCRT<wchar_t> >
>,std::allocator<ATL::CStringT<wchar_t,StrTraitMFC_DLL<wchar_t,ATL::ChTraitsCRT<wchar_t> >
> > >::operator[] (0EE1258h)
00EEE059 mov     esi,esp
00EEE05B push    eax
00EEE05C lea     ecx,[ebp-134h]
00EEE062 call    dword ptr ds:[0F05420h]
00EEE068 cmp     esi,esp
00EEE06A call    __RTC_CheckEsp (0EE1843h)
27 instructions

```

```

plus_plus = my_strings[0] + my_strings[1] + my_strings[2];
00E6E0FB push    2
00E6E0FD lea     ecx,[ebp-128h]
00E6E103 call
std::vector<ATL::CStringT<wchar_t,StrTraitMFC_DLL<wchar_t,ATL::ChTraitsCRT<wchar_t> >
>,std::allocator<ATL::CStringT<wchar_t,StrTraitMFC_DLL<wchar_t,ATL::ChTraitsCRT<wchar_t> >
> > >::operator[] (0E61258h)
00E6E108 push    eax
00E6E109 push    1
00E6E10B lea     ecx,[ebp-128h]
00E6E111 call
std::vector<ATL::CStringT<wchar_t,StrTraitMFC_DLL<wchar_t,ATL::ChTraitsCRT<wchar_t> >
>,std::allocator<ATL::CStringT<wchar_t,StrTraitMFC_DLL<wchar_t,ATL::ChTraitsCRT<wchar_t> >
> > >::operator[] (0E61258h)
00E6E116 push    eax
00E6E117 push    0
00E6E119 lea     ecx,[ebp-128h]
00E6E11F call
std::vector<ATL::CStringT<wchar_t,StrTraitMFC_DLL<wchar_t,ATL::ChTraitsCRT<wchar_t> >
>,std::allocator<ATL::CStringT<wchar_t,StrTraitMFC_DLL<wchar_t,ATL::ChTraitsCRT<wchar_t> >
> > >::operator[] (0E61258h)
00E6E124 push    eax
00E6E125 lea     eax,[ebp-244h]
00E6E12B push    eax
00E6E12C call    ATL::operator+ (0E61B72h)
00E6E131 add     esp,0Ch
00E6E134 mov     dword ptr [ebp-2C4h],eax
00E6E13A mov     ecx,dword ptr [ebp-2C4h]
00E6E140 mov     dword ptr [ebp-2C8h],ecx
00E6E146 mov     byte ptr [ebp-4],0Eh
00E6E14A mov     edx,dword ptr [ebp-2C8h]
00E6E150 push    edx
00E6E151 lea     eax,[ebp-238h]
00E6E157 push    eax
00E6E158 call    ATL::operator+ (0E61B72h)
00E6E15D add     esp,0Ch

```

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```
00E6E160 mov     dword ptr [ebp-2CCh],eax
00E6E166 mov     ecx,dword ptr [ebp-2CCh]
00E6E16C mov     dword ptr [ebp-2D0h],ecx
00E6E172 mov     byte ptr [ebp-4],0Fh
00E6E176 mov     esi,esp
00E6E178 mov     edx,dword ptr [ebp-2D0h]
00E6E17E push    edx
00E6E17F lea     ecx,[ebp-140h]
00E6E185 call    dword ptr ds:[0E8541Ch]
00E6E18B cmp     esi,esp
00E6E18D call    __RTC_CheckEsp (0E61843h)
00E6E192 mov     byte ptr [ebp-4],0Eh
00E6E196 mov     esi,esp
00E6E198 lea     ecx,[ebp-238h]
00E6E19E call    dword ptr ds:[0E85418h]
00E6E1A4 cmp     esi,esp
00E6E1A6 call    __RTC_CheckEsp (0E61843h)
00E6E1AB mov     byte ptr [ebp-4],0Dh
00E6E1AF mov     esi,esp
00E6E1B1 lea     ecx,[ebp-244h]
00E6E1B7 call    dword ptr ds:[0E85418h]
00E6E1BD cmp     esi,esp
00E6E1BF call    __RTC_CheckEsp (0E61843h)
49 instructions
```

The += concatenate created 27 lines of machine code versus the 49 lines of machine code generated by the + operator. So just by the number of instructions created, it can be seen that the + operator will take longer. Looking deeper into the assembly, one can see that the + operator is returning a new buffer for each +, whereas the += operator is doing an actual concatenation on the current CString.

## CONCLUSIONS

It's very important for a developer to understand the complexities of writing code in one way versus another. This report shows that the more efficient way to concatenate CStrings is to use the += operator. Although the performance is not very different when only a few strings are involved, it would be better to just always use the more efficient version.

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### REFERENCES

1. Nealis, T., "std::string Append," Technical Report ARMET-TR-14026, U.S. Army ARDEC, Picatinny Arsenal, NJ 07806, In press.



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