NOTE: This Technical Note has been retired. Please see the Technical Notes page for current documentation.

Technical Note PT32

Performance Tuning with Development Tools

CONTENTS

This Technical Note is a collection of useful ideas and suggestions to help you decrease the time required to compile and link under MPW. Some of the issues are even relevant to any development tools running under the Macintosh environment. The Technote will also clarify what performance tunings work, and which are marginal or may not work at all.

[May 01 1992]

Introduction

This Technical Note contains information that will help you improve both compilation and linking times, and also point out about performance tricks that are marginal, or may not work at all. Most likely this information will be updated and modified as we gain more knowledge of how to speed up compilations and link stages. This Note is biased towards the `MPW` environment. However, there are many ideas that can be used with any other Macintosh development platforms. The issues are ordered from hardware- or system-related issues to specific MPW and MPW tool issues, and these are not listed in any particular order of efficiency.

Many of these ideas are benchmarked and the results are marked with a special note at the end of the paragraph . The equipment/environment consisted of:

- Macintosh 900 Quadra, 160Mb internal hard disk, 20Mb physical RAM memory, no VM (unless stated)
- System 7.0.1 + TuneUp
- MPW 3.2 4Mb application heap, 256k file cache
- No extensions loaded, no network
- MacApp 3.0 Calc application source, C++ (when applicable)

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Hardware Issues

Accelerator Cards

We at DTS have had mixed input about using CPU accelerator cards. In general they speed up number-crunching. However, they don't help with file I/O bottleneck situations. Also they can cause compatibility problems with the tools, so we strongly recommend taking out the card for testing if you encounter weird problems during compilation or linking.

Before you buy a card, contact the appropriate accelerator card tech support group, and ask about the compatibility of their card with various Macintosh development systems. Try to borrow a card for a quick test to figure out if buying the card is justified or not and if it works with the particular development tools needed. Remember that accelerator cards based on NuBus(TM) can easily congest the NuBus bus (which has a 10 MB/sec limit on data transfers). Any possible savings in CPU execution could be lost in the NuBus transfers.

SCSI I/O Cards and Hard Disk Access Times

File I/O is one of the known bottlenecks that affect MPW performance (however, it's not the only bottleneck). Faster NuBus SCSI cards (like SCSI-2 cards) should certainly improve the file I/O; how much depends on the file I/O access figures. Also, shop around for hard disks with fast access times.

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System Issues

Background Processes

Every background process, including the Finder, takes CPU cycles that could be used for compilation and linking. Try to limit the background tasks on your compiling system. If possible turn off any unnecessary inits and drivers.

External Sources of Interrupts

You should be aware that the development machine connected to a network will receive outside interrupts as part of the network protocol handling (as in AppleTalk), and this will also consume needed CPU cycles. For example, System 7 Personal FileShare requires a lot of attention from the system itself. This is also true of any other background communication protocol handling. The best possible case is a standalone development system. However, for practical reasons (like accessing common volumes) a developer can seldom afford to configure a standalone environment. If possible, minimize the network access on the development system.

If a server is connected to the system and is not used, the Finder still attempts to keep its desktop in synch with the server. This consumes CPU cycles. If the server and the network are busy then the machine is stuck waiting. If possible, always remove servers from the desktop when they are no longer needed.

```
    [[Delta]] System in network + inits+ =
          404s, no-network System =
          379s, savings       6.25%.
          + mail services,
          4 servers on desktop,
          1 application in memory
```

File Cache

We suggest that you experiment with your particular system configuration, there is no magic value which we could recommend. There's however a difference between System 6.0.x and 7.x. Large cache sizes in System 6 will not improve the performance due to a bug, which is fixed in System 7. If your development tool is mostly in memory during the execution, many of the resources and data files may be cached in memory between the execution stages. Following is a test where we changed the cache size between 32k and 4096k while compiling the same sources. As shown we didn't directly find an optimal value, so the 96k value is a good approximation.

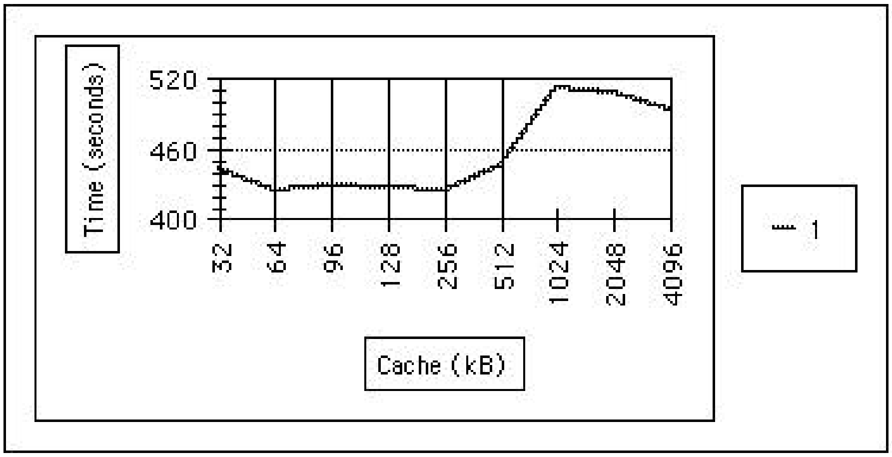

Figure 1. cache size vs. compilation time

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System 7 Virtual Memory

The use of virtual memory is recommended when you would like to have many development tools running at the same time. However, VM is much slower than real memory; it constantly needs to read/write to the much slower hard disk. One exception is the IIci with its built-in video. IIci has a non-contiguous memory map, and uses the MMU to map the logical addresses. The algorithms used by the ROM are slower than the ones used by VM. However the access gates slower if a page fault occurs.

Note also that 32-bit mode runs faster than 24-bit mode.

```
    [[Delta]] VM on+ =  481s, VM off =  400s, savings   16.8%.
```

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Compiler Issues

Compiler Flags

Eliminate any compiler flags that are not necessary for the code compilation. For example, optimization flags take more CPU cycles, and in many cases the code produced without optimization is OK for a quick syntax or functionality test. Read the manuals carefully; they should indicate which flags are default ones. Note also that the MacApp has its own `Startup` file where many compiler flags are defined.

The `-sym on/full` flag will trigger `.SYM` file information generation, and this takes time. If possible avoid symbolics generation until you really need to debug.

Selected #include File Handling

A larger percent of a typical compile is spent reading the header files, so reading them only once for each source file compilation is a win. We are talking about cases where various source files each want to include the same header file. The MPW C compiler has a special pragma called #pragma once, which will make sure that each source file with this statement at the top of the file will be read in only once. However this will not work with other languages - like C++ - so the following guidelines are useful:

In your individual source files, bracket your C++ include files so that they are not read more than once during a compilation of a source file:

```
/ / Utilities.cp

#ifndef _UTILITIES_
#include "Utilities.h"
#endif _UTILITIES_
```

Of course, you also need to put bracketing into your local include files so that things don't go haywire if you do include the same file twice (note that we recommend using only one underline, because ANSI C has reserved the use of two underlines):

```
// Utilities.h

#ifndef _UTILITIES_
#define _UTILITIES_
// definitions

#endif _UTILITIES_
```

One trick is to define a global `IncludeFiles.h` file, which contains all files needed for the other header files, and include it on demand inside the other header files, using the `#ifndef` trick. A `#pragma once` statement placed first in a C header file provides the same functionality. However, we can't guarantee that the `#pragma once` statements in C++ code end up in the right places with the generated C code, so don't use this with C++.

```
    [[Delta]] No #include labels = 183s,
          include labels = 174s, savings 6.45%.
```

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C / C++ Compiler Issues

Load/Dump

`load/dump` is described in the MPW C++ Release Notes. It provides the biggest single performance improvement possible when using MPW C++. Use the `-load` and `-dump` flags instead of the MPW C `#pragma load/dump` statements, because they work differently. `#pragma load` and `#pragma dump` placed directly in C++ may have Cfront generate code that appears before the pragma and thus could cause the `load/dump` to work incorrectly.

MPW C also has this feature, implemented using #pragma load and #pragma dump - compile time savings are similar to those found in C++. For more information on how to use this feature, please refer to the MPW C 3.0 release notes, pages 40-41.

Tradeoffs Between Compiling Small and Large Files

Each time CPlus is triggered, MPW will load in resources needed for the compiler. This also happens when CPlus triggers the C compiler. In the case of a compilation of 10 files, the C++ and C resources are loaded 10 times in a row.

There are cases where a huge file compilation is faster than compiling a number of smaller files. The overall trick is to create dependencies (Makefiles) where as few files as possible are recompiled when something changes.

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Pascal Compiler Issues

Limit Symbol Table Generation

The `-p` switch on the Pascal compiler is useful to determine where the compiler is spending its time. For example, with MacApp the compiler should spend a lot of time inside the MacApp units and in the `PInterfaces` files when discarding predigested symbol resources on the interface files and reanalyzing the source.

The goal is to configure a standard set of interface files so that we can use the precompiled symbol information. Changing the order of includes or `USES` statements could cause these resources to be rebuilt, taking extra time.

Here is a possible strategy to help you analyze the information from the compiler and define strategies that will minimize the need for resources and make the compilation faster:

1. ALL units should use `Types`, `QuickDraw`, `Packages`, `SANE`, and `Printing` (if needed).
2. When additional units are required, *always* use units from the newer, smaller groupings: `Events`, `Controls`, `Desk`, `Windows`, `TextEdit`, `Dialogs`, `Fonts`, `Lists`, `Menus`, `Resources`, `Scrap`, and `ToolUtils` {instead of `ToolIntf`} `OSUtils`, `Files`, `Devices`, `DeskBus`, `DiskInit`, `Disks`, `Errors`, `Memory`, `OSEvents`, `Retrace`, `SegLoad`, `Serial`, `ShutDown`, `Slots`, `Sound`, `Start` and `Timer` {instead of `OSIntf`} and `Script`, `Palettes`, `Picker`, `Perf`, `DisAsmLookup`, `AppleTalk`.
3. Note that if you mix references to newer and older files it will take longer to compile.
4. Always use units in the same order. The Apple units set compile flags that *must* be identical the next time a unit is used or the compiler will not use the symbolic resources.
5. The MacApp units also set compile flags, so they should appear after the `MPW:Interfaces:PInterfaces` units and always in the same order.
6. Keep your own units in a consistent order in each USES statement, especially if you use compiler variables in your source.
7. Adjust your build scripts to build units in the same order they are listed in your USES statements.
8. As you clean up the units, compile them in a full build with the `-p` compiler option to verify the results of your work. The output will indicate when the compiler uses the resources.

If you clean up your files in the order in which the units are built, you will begin to accumulate savings as you go along. However, don't expect to see a tremendous difference until nearly all your USES statements have been cleaned up. When an uncleaned unit is compiled, the consistency of the symbol resources is spoiled and the compiler starts parsing resources again. Moreover, it leaves the units in this inconsistent state, so the next build must begin by rebuilding the resources in a consistent manner.

Once the cleanup is complete, your application should build at its optimum rate. If you are already pretty clean in your USES statements, you should be getting near optimal performance.

If you haven't already done so, consider switching to the 3.0/C-style separate interfaces instead of using `OSIntf` or `ToolIntf`. Unless you use almost all the files included by these old-style units, you should use the files as separate units, and get only what you need.

In all cases use `Types.p` instead of `MemTypes.p` and `Packages.p` instead of `PackIntf.p`.

Try not to rely blindly on the auto-inclusion feature of the new interfaces. If you let `Packages` include `Types` in one file and then use `Types` before using `Packages` in the next file, you'll get "symbol table churning": compile-time variables will be different and the symbol table resources will have to be rebuilt each time.

Structure your `Make` file so that the units that come first in your USES clause get compiled before later units and the main program. The symbol table resources for a unit are always rebuilt when the unit is compiled. So if you change a unit and the main program, and your `Make` file builds the main program first, the symbol table resources for the unit will get built when the program is compiled, and again when the unit is compiled.

Use the `-p` option every now and then to see how things are going. Maybe you have compile-time variables that are causing symbol table churning, or maybe the resource fork of a file has become corrupt. Maybe you don't have enough memory to create the symbol table resource (MacApp needs more than a 4 MB partition, and use `-mf` with all tools if possible). Most of the possible inefficiencies in reading or writing symbol table resources can be displayed only by use of the `-p` option

If you use MacApp and switch between versions often (`Debug/noDebug` and so on), you can put the directive `{$K $$Shell(ObjApp)}` before the first unit in your USES clauses. This will create the symbol table resources in files in the same directory as the program's object files. So as you switch from `:.Debug Files:` to `:.Non-Debug Files:` the right set of symbol table resources will already be built.

Precheck the Pascal Syntax

You might precompile the code using Pasmat before the Pascal compiler is used, which could be helpful for quickly finding syntax errors in the code without the penalty of running the full compiler. You might define a command key that performs the operation, as in the following:

```
AddMenu MyMenu 'Pasmat {Active}.[[section]]/[[pi]]'
    '[[partialdiff]]
    (    Pasmat <"{Active}.[[section]]" >"{TemporaryFile}"
    >= "{ErrorsFile}" [[partialdiff]]
    && Catenate "{TemporaryFile}"
    > "{Active}.[[section]]" ;[[partialdiff]]
        Delete -y "{TemporaryFile}" [[partialdiff]]
    ) || Alert <"{ErrorsFile}"'
```

You might also use the `-c` flag with the Pascal compiler for syntax checking only.

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Linker Issues

Limit Symbol Table Generation

In general it takes a lot of time for the linker to build the final .SYM file. Try to avoid building symbol files unless needed (like when stuck with a problem in the source code). In many cases the `-msg full` (or `-Names` flag in MacApp) compiler flag for MacsBug name generation might be OK for a test of where the application crashes.

You might also create a limited set of SYMBOLIC (.SYM) information. Here's an example from MacApp 3.0 of how this could be achieved (in the case of general C++ code, just specify'`-sym on'` in the C++ compiler for those files that you need for debugging). This technique will also save both RAM and disk space.

```
#############################################################
# L I B R A R Y   D E P E N D E N C I E S
#############################################################
"{ObjApp}{LibName}"[[florin]][[florin]] [[partialdiff]]
   {LibObjs}
   IF {MacAppLibrary} || {LibName} !~ /MacApp.lib/ # Special trick to keep
   MacApp libraries from building
   {MAEcho} {EchoOptions} "Libbing:       {LibName}"
   SET XToolStartTime 'DATE -n'
#  {MALib} [[partialdiff]]
#  {LibOptions} [[partialdiff]]
#  {OtherLibOptions} [[partialdiff]]
#  {LibObjs} [[partialdiff]]
#  -o "{ObjApp}{LibName}"
   execute "Skinny Lib"      <+++++++++ new script file

File:  Skinny Lib   ----------------------------

directory "{malibraries}.nodebug names sym nosys7:"
delete -i macapp.lib

lib -mf -w -sym off -o macapp.nosym [[partialdiff]]
   Geometry.cp.o PascalString.cp.o Toolbox.cp.o UAppleEvents.cp.o
   UAssociation.cp.o [[partialdiff]]
   UBusyCursor.cp.o UClipboardMgr.cp.o UCPlusTool.cp.o UDebug.a.o
   UDebug.cp.o [[partialdiff]]
   UDeskScrapView.cp.o UEditionDocument.cp.o UErrorMgr.cp.o
   UFailure.a.o UFloatWindow.cp.o [[partialdiff]]
   UGeometry.cp.o UGrabberTracker.cp.o UKeySelectionBehavior.cp.o
   UMacAppGlobals.cp.o [[partialdiff]]
   UMacAppUtilities.cp.o UMemory.a.o UMenuMgr.cp.o UMenuView.cp.o
   UPascalTool.p.o [[partialdiff]]
   UPatch.cp.o USection.cp.o USectionMgr.cp.o UStream.cp.o
   USynchScroller.cp.o [[partialdiff]]
   UProjFileHandler.cp.o UScroller.cp.o UTabTEView.a.o
   UTabTEView.cp.o [[partialdiff]]
   UTearOffMenuView.cp.o UTECommands.cp.o UTEView.cp.o
   UTranscriptView.cp.o [[partialdiff]]
   UDependencies.cp.o UDesignator.cp.o UTabBehaviors.cp.o

#lib -mf -w -sym off,NoLabels,NoLines,NoVars -o
        macapp.justTypes[[partialdiff]] lib -mf -w -sym off -o
macapp.justTypes[[partialdiff]]
   UCommand.cp.o UCommandHandler.cp.o MacAppTypes.cp.o UAdorners.cp.o
   UBehavior.cp.o [[partialdiff]]
   UDrawingEnvironment.cp.o UEvent.cp.o UFile.cp.o UFileHandler.cp.o
    UMemory.cp.o [[partialdiff]]
   UIterator.cp.o UPopup.cp.o UViewBehavior.cp.o UViewServer.cp.o

lib -mf -w -sym on -o macapp.lib macapp.nosym
macapp.justTypes[[partialdiff]]
   UApplication.cp.o UControl.cp.o UDialog.cp.o UDialogBehavior.cp.o
   UDocument.cp.o [[partialdiff]]
   UEventHandler.cp.o UFailure.cp.o UFileBasedDocument.cp.o
   UGridView.cp.o [[partialdiff]]
   UList.cp.o UObject.cp.o UPascalObject.a.o UPascalObject.cp.o
   UPrintHandler.cp.o [[partialdiff]]
   UPrinting.cp.o UView.cp.o UWindow.cp.o
```

```
    [[Delta]] .SYM generated = 379 s, no .SYM
```

Use Libraries If Possible

The linker will perform much faster if you link together library files (created by the Lib tool) than if you separately compile .o files. Consult the latest MPW documentation which describes various ways of using the Lib tool with projects.

CODE Resources

If you have code resources that do not make any intersegment calls (such as standalone code and `XCMD` style code resources), you can use the `Rez` tool to add these resources directly to the binary instead of using the link tool. This should save some time; how much depends on the actual project.

Global Data

The link tool will build a complete image of the globals to be initialized. If the global area is large, this might take a long time. Try to avoid extensive and unneeded use of global data.

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C++ Code Issues

Smaller Files Compile Faster

Split huge source and header files into smaller modules and create dependencies in the Makefile that will trigger compilations only when a particular file has changed. A known caveat with C++ is the `vtable` consistency. Sometimes the vtables have to be created from scratch in order to synchronize the `vtable` information. If the compilation and linking phase has generated a binary, but when you are running the application it has problems, try to recompile most or maybe all sources for a quick test in order to see if the problem has to do with vtables.

Don't Include All Class Headers

If possible place include statements with C++ classes internally used in the .cp file instead of in the header (.h) file. When developers are using a particular header file, they don't need to include class headers that are not needed, and this saves some time. In general try to avoid unnecessary inclusions of classes.

C++ Dump/Load

One problem with compiling object-oriented programs has to do with the parsing of header files. Generally, 80% of the compile time is spent parsing header files. However, most header files remain unchanged for long periods of time during the programming phase. So the header files are reread and reparsed, time after time.

C++ dump/load solves this problem by dumping the header file information to a single file. During compilation of class methods, the compiler loads from this dump file each time it needs the header file information. You can get even more speed by placing all the dump and object files on a RAM disk.

To use dump/load you need to decide which header files are static and not subject to change. For MacApp, the obvious choice is the MacApp class header files. For other complex frameworks, consider only the most stable header files for the dump file. If you alter header files often, the compiler has to create a new dump file, and the dumping process takes a long time.

For more general C++ dump/load guidelines, please consult the MPW C++ Release Notes.

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MacApp Code Issues

Using Dump/Load With MacApp

`MABuild` has a flag called -`CPlusLoad`. When this is present, the C++ compiler dumps the MacApp header file information to a folder called `Load Files` inside the MPW folder. This happens during the first compile only. A dump file can take 1 to 2 MB of space, so check your disk space before doing the dump. Also remember that if you have many release versions of the same header files that are dumped, you need to delete the earlier dump files; otherwise you will encounter mysterious bugs.

Dump/load requires lots of heap space for the tools, so now is the time to start using the `-mf` option with `CPlus`, `Link`, and `Lib`. Or increase the MPW application heap size--depending on the size of your sources, up to 4 MB or more. If the CFront tools don't have enough memory for the memory-consuming part of the parsing, error messages such as *"free store exhausted"* will be displayed.

MacApp has a special startup file in the MacApp folder where you can specify default settings. One of the variables defined in this file is `MABuildDefaults`:

Uncomment this line and restart MPW, or select and execute the command. The next time you build your MacApp application, `MABuild` will automatically use the MacApp header files to create a dump file inside the '`MPW:Load Files`' folder. Note that this is now the default case with MacApp 3.0.

You can go one step further and specify that additional header files should be dumped. To do this, edit the `MacApp:Tools` file called `'Build Rules and Dependencies.'` Here's an excerpt from that file:

```
# Load/Dump files must be kept current for C++ too
{CPlusLoadFiles}    [[florin]]    {MacAppCPlusIntf}
    {MAEcho} {EchoOptions} "C++ Load/Dump: UMacApp.h.dump"
    IF 'EXISTS {CPlusLoad}' != "
        Delete {CPlusLoad}
        END
    {MACPlus} [[partialdiff]]
        {CPlusOptions} [[partialdiff]]
        {OtherCPlusOptions} [[partialdiff]]
        -i "{SrcApp}" [[partialdiff]]
        -i "{MACIncludes}" [[partialdiff]]
        "{MACIncludes}UMacApp.h" [[partialdiff]]
        -mf [[partialdiff]]
        # Any other files you want to include in the dump
            could go here [[partialdiff]]
```

If you're sure that you will repeatedly include certain additional header files in the MacApp dump file, you can add them to this file. Any building block headers (`U~.h` files) that are likely to be stable are good candidates.

You can also define build rules for dump/load files in the MAMake file for each MacApp project. This way you can have different dump/load definitions for various permutations of source code and header code combinations. Writing your own MAMake dump rules gives you better control over what is to be dumped. Instead of generically dumping all MacApp header files, you can dump only those MacApp and application header files actually used-- you don't have to dump all the MacApp header files as MacApp's default C++ dump does. This saves time and disk space.

This works well for handling header files that are part of your own project as long as you don't frequently change the header files, which triggers a costly dump operation. Here are some guidelines:

- You must create a header file dependency rule for the dump file if you want dependencies operating on the header file changes.
- Use `{SrcApp}` prefixes for the application source code file names, and `{ObjApp}` prefixes for the application object code file names.
- You will be overriding most of the basic building rules, so if you want the MPW shell to show what it is doing, add an `Echo` statement as in the original rules.

The C++ Release Notes discuss in great detail how to build the dump file header file. Once again, the trick is to move all static header files to one single file, and call it "`MyAppDump.h`" or something similar. In all the other header files, include the following:

```
    #ifndef __MYAPPDUMP__
    #include "MyAppDump.h"
```

Do the same `ifndef` trick with the included header files in the dump header file, so that the compiler won't need to include the file many times. Build a rule for dumping the `MyAppDump.h` file, or do it by compiling the header from the MPW command line.

Sometimes a header file is static; then suddenly you are tearing your object framework apart in a frenzy, making incremental changes. A good way to support this would be to use multiple dump files, where sometimes you dump and load from many files, but other times you load from only one dump file, allowing the compiler to parse the header file that is subject to change. (This would be faster when header files are changing, because the dump phase takes a long time.)

Alas, it's not likely that there will ever be support for multiple dump files in MPW C++ because dump files contain structures that are hard to merge. You can achieve a similar functionality using flags inside the header files. You could instruct `MABuild` to dump your own header files in addition to the basic header files. This is done with a programmer-defined MABuild option:

This `qOwnDump` flag controls use of dump files within the header files via a simple `#ifdef qOwnDump` directive (see sample code in the Snippets collection(Developer CD, ETO CD, AppleLink, ftp.apple.com). By using this directive, you can exclude your header files from the dump phase while incrementally changing header files; when again working with method implementations, so that headers are static, you can again dump your header files.

```
    [[Delta]] No dump files =  818 s, dump file+ =  660s, savings   19.3%.
```

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MPW Issues

More RAM Memory

More memory means more application heap space, and this means less segment loading in cases where segments are purged out of memory in memory-tight situations. If the MPW memory partition is big enough most tools could stay in the MPW heap, and this improves the performance, but not much! Note that you don't need to go overboard with the application heap space. The peak parts of memory use could be handled with the `-mf` `MultiFinder` temporary memory flag which is implemented with our compilers, linker, and `Lib` tools. For instance a 4Mb MPW partition is suitable for MacApp programming if the `-mf` flag is defined for the compilers linker and Lib.

```
    [[Delta]] 4Mb heap =   379 s, 12Mb heap =  379 s, difference 0%.+
```

RAM Disks

To avoid file I/O bottlenecks you might think about using a RAM disk. The following order is based on the list of the most important folders/files, and if you have more RAM disk space you could include more from this list until you have most of the development environment and the sources on the RAM disk (the most extreme case). In some cases, like the first three examples, all you need to do is to redefine the exported value in an MPW startup file (the last one!), as in:

```
Set CPlusScratch "RAMDisk:"
```

In other cases you need to copy the files/folders to the RAM disk, and add the paths to the new folder in such a way that the MPW environment will look into the particular folder first , as in:

```
Set Commands "RAMDisk:Tools:,{Commands}"
```

Here's the recommended list:

`{MATemporaries}` temporary folder for files that MacApp MaBuild creates

`{CPlusScratch}` temporary folder for files that MPW C++ creates

{MALoadFiles} MacApp dump/load files folder

MPW:Tools tools (like compilers) for faster load into memory

MPW:Scripts scripts, for faster load into memory

{Libraries} general MacOS libraries, for faster load

{CLibraries} or

{PLibraries} general C/Pascal libraries for faster load

{MALibraries} MacApp libraries (.lib, .rsrc files)

. . . your own project files . . .

Any other possible additions are MPW and MacApp header files and the actual MPW shell itself, including any other development tools. However, these take a lot of space, so we are talking about a huge RAM disk. If you have a +50 MB RAM disk, you might even place the whole MPW and MacApp folders on the RAM disk, which is the quickest way to get the benefits of such a large RAM disk. However, you then need a RAM disk utility which will save and restore the contents if the system is shut down.

```
    [[Delta]] No RAM disk = 379 s, 4Mb RAM disk+ = 342 s, savings 9.8%.
```

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Testing

The following MPW script is useful for testing purposes:

```
Echo -n > "{MPW}Dump"                    # specify output
                                  file/window
Open "{MPW}Dump"

for cases in 1 2 3 4 5                    # define how many tests
    Echo "Test Number "{cases}
    set StartTime 'Date -n'
    set exit 0
    MaBuild -debug -sym Calc  [[Sigma]][[Sigma]]
        "{MPW}Dump"    # place whatever job
here
    delete -y *Debug~                    # clean up afterwards
    set exit 1
    set TimeNow 'Date -n'
    set Elapsed 'Evaluate {TimeNow}-{StartTime}'
    set Elapsed "'Date -c {Elapsed} -t'"
    If "{Elapsed}" =~ /12:([0-9]+:[0-9]+)reg.1 [AP]M/
       Set Elapsed "0:{reg.1}"
    Else If "{Elapsed}" =~ /0*([0-9]+:[0-9]+:[0-9]+)reg.1 [AP]M/
       Set Elapsed "{reg.1}"
    End
    Echo "[[partialdiff]]t[[lozenge]] Build time: {Elapsed}"
```

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Conclusion

The four most valuable performance improvements are:

1. RAM disk use (the more you could place on the RAM disk, the better performance)
2. Don't compile and link with the `-sym on` option unless needed
3. Use libraries
4. Avoid compiling/linking, use tools which will postpone unneeded compilation and linking

Use common sense and consider whether a particular scheme will require more resources and/or memory. Carefully follow Apple announcements about new tools and development environments that might fix bugs that have caused slower performance, or brand-new tools that address performance issues.

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References

MPW Documentation

NuBus(TM) is a trademark of Texas Instruments.

Acknowledgements

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