C#-Performancetuning

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Your Host

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Agenda (German)

Der Code ist fertig, die Kunden beschweren sich über schlechte Performance. Was nun? In dieser zweiteiligen Session zeigt Rainer Stropek Wege aus solchen Krisen. Im ersten Teil erarbeiten wir die Grundlagen.

- Was beeinflusst die Performance von .NET-Anwendungen?
- Welche Mythen gibt es, die man getrost vergessen kann?
- Warum beeinflussen JIT und Garbage Collector die Performance so stark?
- Wie bereitet man Performanceprofiling richtig vor?
- Welche grundlegenden Techniken gibt es dafür?

Solche und ähnliche Fragen sind Thema der Session.

Im zweiten Teil gehts ins Detail. Rainer zeigt anhand praktischer Beispiele, wie man Tools in und um Visual Studio verwendet, um Performancekillern auf die Spur zu kommen. Sie lernen unter anderem die Profiling-Tools von Visual Studio und das Microsoft-Werkzeug PerfView kennen. Exemplarisch wird Rainer in der Session auch Unterschiede zu kommerziellen Profiling-Werkzeugen demonstrieren.

Why Optimizing? Examples …

Customer satisfaction

Customers report performance problems
Reduce churn rate
Tip: Ask you users if they are leaving because of poor performance

Raise conversion rate

Consider the first impression potential users have from your software
Tip: Ask your users why they are not buying

Reduce TCO of your application

Performance problems waste your user's time = money
Reduce TCO for your customers by lowering system requirements
Cloud environment is too expensive

Anti-Patterns

How to ruin every optimization project

Optimization Anti-Patterns

Add optimizations during initial development

Write obvious (not naïve) code first → measure → optimize if necessary
Perf problems will always be where you don't expect them

Optimize code without measuring

Without measuring, optimized code is often slower
Make sure to know if your optimization brought you closer to your goals

Optimize for non-representative environments

Specify problematic environments as accurate as possible
Test your application on systems similar to your customers' environments
Hardware, software, test data (consider data security)

Optimization Anti-Patterns

Optimization projects without concrete goals

Add perf goals (quantifiable) in requirements
You could spend endless time optimizing your applications
Optimize to solve concrete problems (e.g. for memory, for throughput, for response time)

Soft problems or goals

Strive for quantifiable perf metrics in problem statements and goals
Objective perf problems instead of subjective stories

Optimize without a performance baseline

Always know your performance baseline and compare against it
Reproducible test scenarios are important

Optimization Anti-Patterns

Optimize without profound knowledge about your platform

Know your runtime, platform, hardware, and tools

Optimize the wrong places

E.g. optimize C# code when you have a DB-related problem

Spend enough time on root-cause analysis for your perf problems

Ship debug builds

Release builds are much faster than debug builds

Optimization Anti-Patterns

Optimize everything

Focus on performance-critical aspects of your application instead
Pareto principle (80/20)

Architect without performance in mind

Avoid architecture with inherent performance problems
If necessary, consider prototyping in early project stages

Confuse performance and user experience

Async programming might not be faster but delivers better user experience

Optimization Projects

Prepare optimization projects for success

Good Optimization Projects

1. Plan for it

Put it on your backlog
Get (time) budget for it (time-boxing); consider a business case for your optimization project
Make yourself familiar with corresponding tools

2. Prepare a defined, reproducible test scenario

Hardware, software, network
Test data (e.g. database)
Application scenarios (automate if possible)

3. Measure performance baseline

E.g. CPU%, memory footprint, throughput, response time

Good Optimization Projects

4. Define performance goals

Must be measurable
Involve stakeholders (e.g. product owners, customers, partners, etc.)

5. Optimize – Measure – Analyze Cycle

Don't change too many things at the same time
Measure after optimizing
Compare against baseline; if necessary, reset your baseline
Check if you have reached performance goals/time-box

6. Ask for feedback in real-world environments

E.g. friendly customers, testing team

Good Optimization Projects

7. Document and present your work

Architecture, code, measurement results
Potentially change your system requirements, guidelines for admins, etc.
Share best/worst practices with your peers

8. Ship your results

Remember: Ship release builds
Continuous deployment/short release cycles let customers benefit from perf optimizations
Consider hotfixes

Use the Cloud

Easy to build different execution environments

Number of processors, RAM, different operating systems, etc.
Performance of database clusters
Don't wait for admins to setup/deliver test machines/VMs

Design for scale-out and micro-services

Easier to add/remove VMs/containers than scaling up/down
Use micro-services and use e.g. Azure Websites or Docker to map to server farms

Extremely cost efficient

You only pay for the time your perf tests last
You can use your partner benefits, BizSpark benefits, etc.

Use the Cloud

Less data security issues if you use artificial test data

Ability to run large-scale load tests

Gather perf data during long-running, large-scale load tests

SaaS enables you to optimize for a concrete environment

Economy of scale

Perf Influencers

What influences the performance of your applications?

Performance influencers

Performance of storage system

Database, file system, etc.

Performance of services used

E.g. external web services

Network characteristics

How chatty is your application?
Latency, throughput, bandwidth
Especially important in multi-tier applications

Performance influencers

Efficiency of your algorithms

Core algorithms
Parallel vs. sequential

Platform characteristics

JIT compiler
Garbage collector

Hardware

Number of cores, 64 vs. 32 bits, RAM, SSDs, etc.

Database

DB performance considerations

Influencers

Network connection to the database

Latency, throughput

Do you really need all the data you read from the database (e.g. unnecessary columns)?

Generation of execution plan

Statement parsing, compilation of execution plan

Bound to CPU-power of database server

Can't you simplify your query to speed up parse and compile time?

Query execution

Complexity of query, index optimization, etc.

You might need a database expert/admin to tune your SQL statements

Influencers

Process DB results

Turn DB results into .NET objects (O/R mappers)

DB access characteristics

Many small vs. few large statements

Lazy loading

DB latency influences DB access strategy

Finding problematic queries

SQL Server Profiler

Create and manage traces, replay trace results
Will pre deprecated

SQL Server Extended Events

Collect information to troubleshoot or identify performance problems

Dynamic Management Views (DMV)

sys.dm_exec_query_stats
sys.dm_exec_cached_plans
Monitoring Azure SQL Database Using DMVs

```
SELECT TOP 10 query_stats.query_hash AS "Query Hash",
   SUM(query_stats.execution_count) AS "Execution Count",
    MAX(query_stats.total_worker_time) AS "Max CPU Time",
    MIN(query_stats.statement_text) AS "Statement Text"
FROM
    (SELECT QS.*, SUBSTRING(ST.text, (QS.statement_start_offset/2) + 1,
       ((CASE statement_end_offset WHEN -1
          THEN DATALENGTH(st.text)
          ELSE QS.statement_end_offset END
       - QS.statement_start_offset)/2) + 1) AS statement_text
     FROM sys.dm_exec_query_stats AS QS
     CROSS APPLY sys.dm_exec_sql_text(QS.sql_handle) as ST)
       as query_stats
GROUP BY query_stats.query_hash
ORDER BY 3 DESC;
GO
```

DMVs

Find long running queries in Azure

See also https://msdn.microsoft.com/en-us/library/azure/ff394114.aspx

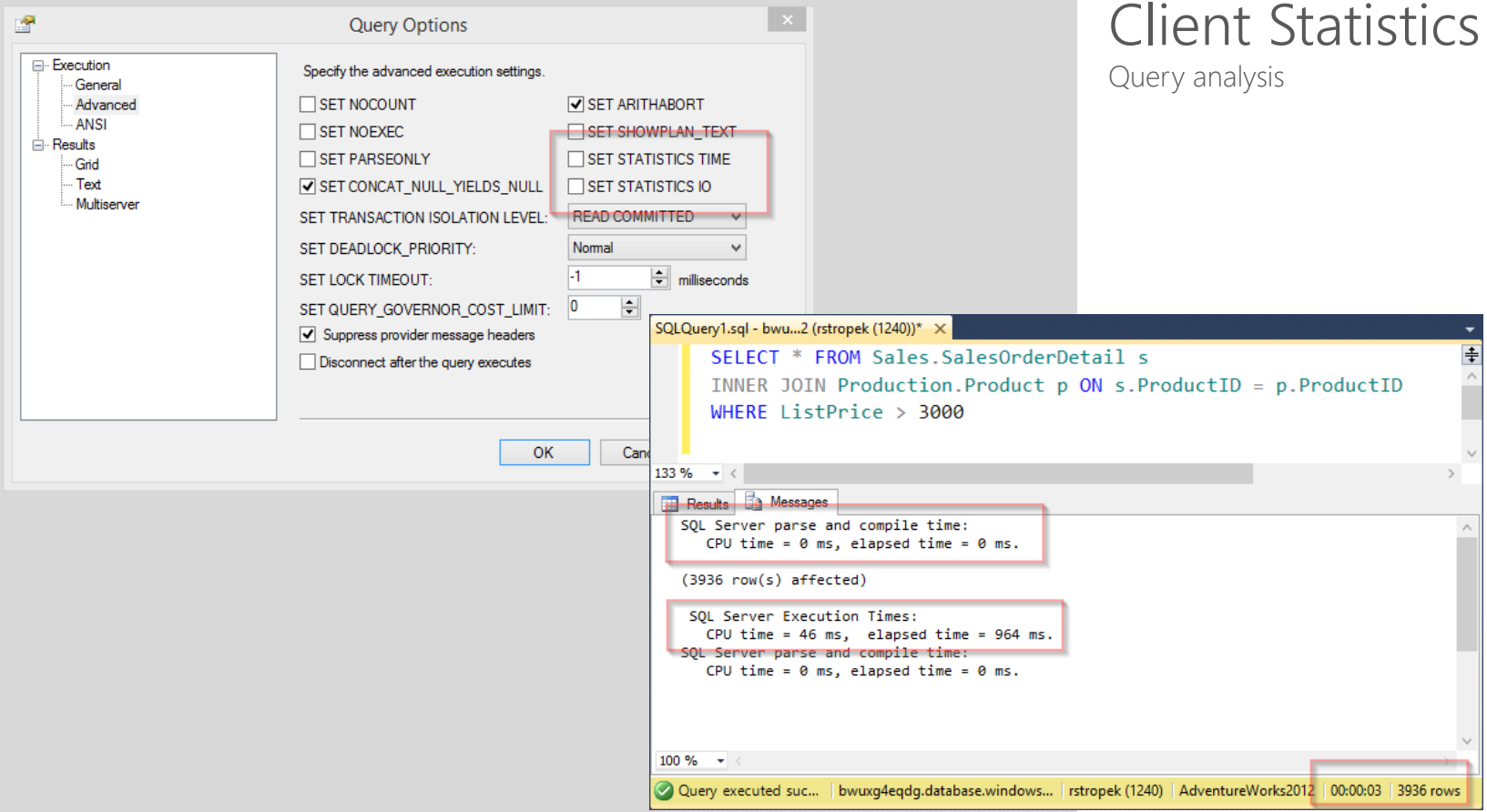
Finding problematic queries

TODO: IntelliTrace

TODO: RedGate SQL

Client Statistics

Query analysis

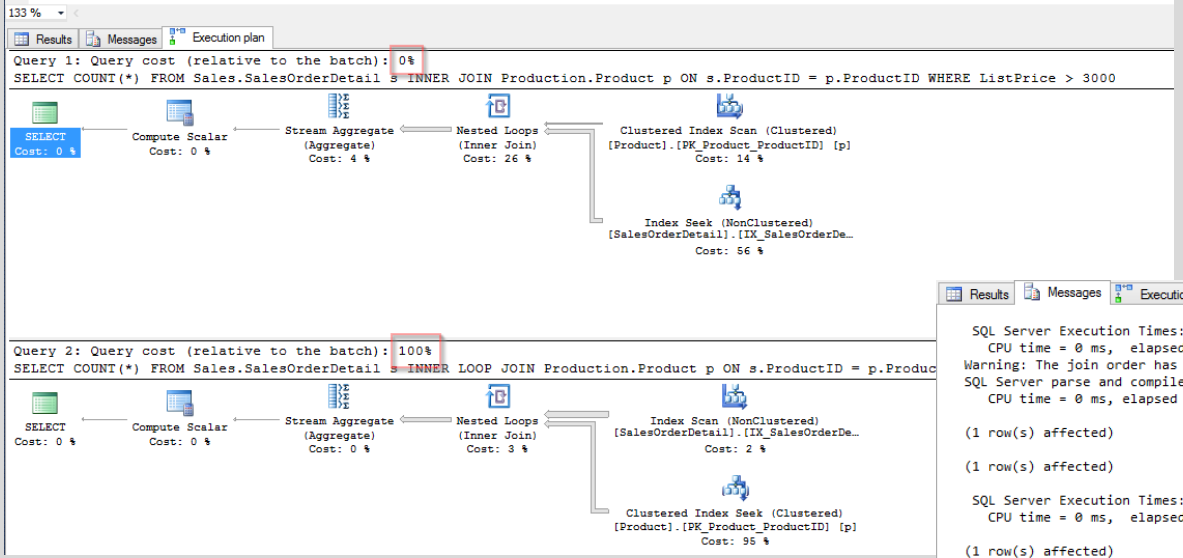


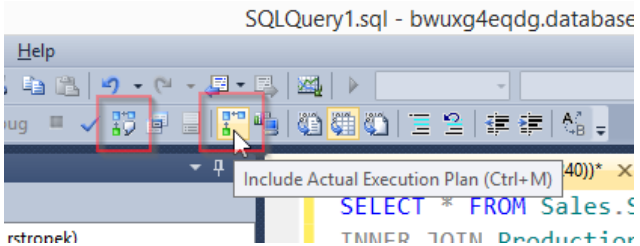
Execution Plans

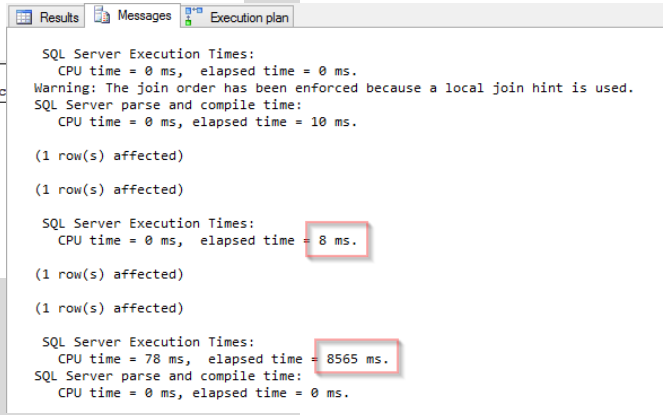
Query analysis

```
SELECT COUNT(*) FROM Sales.SalesOrderDetail s
INNER JOIN Production.Product p ON s.ProductID = p.ProductID
WHERE ListPrice > 3000

SELECT COUNT(*) FROM Sales.SalesOrderDetail s
INNER LOOP JOIN Production.Product p ON s.ProductID = p.ProductID
WHERE ListPrice > 3000
```







Services, Network

Things to Consider

How often do you call over the network?

Latency, speed-of-light problem
Ratio between latency and service operation
Consider reducing network calls with caching (e.g. Redis cache) …
… but make sure that you cache doesn't make perf worse!

How much data do you transfer?

Transfer less data (e.g. unnecessary database columns)
Make protocol more efficient (e.g. specific REST services or OData instead of generic services)

Measuring is important

The tools you use might do things you are not aware of (e.g. OR-mapper)

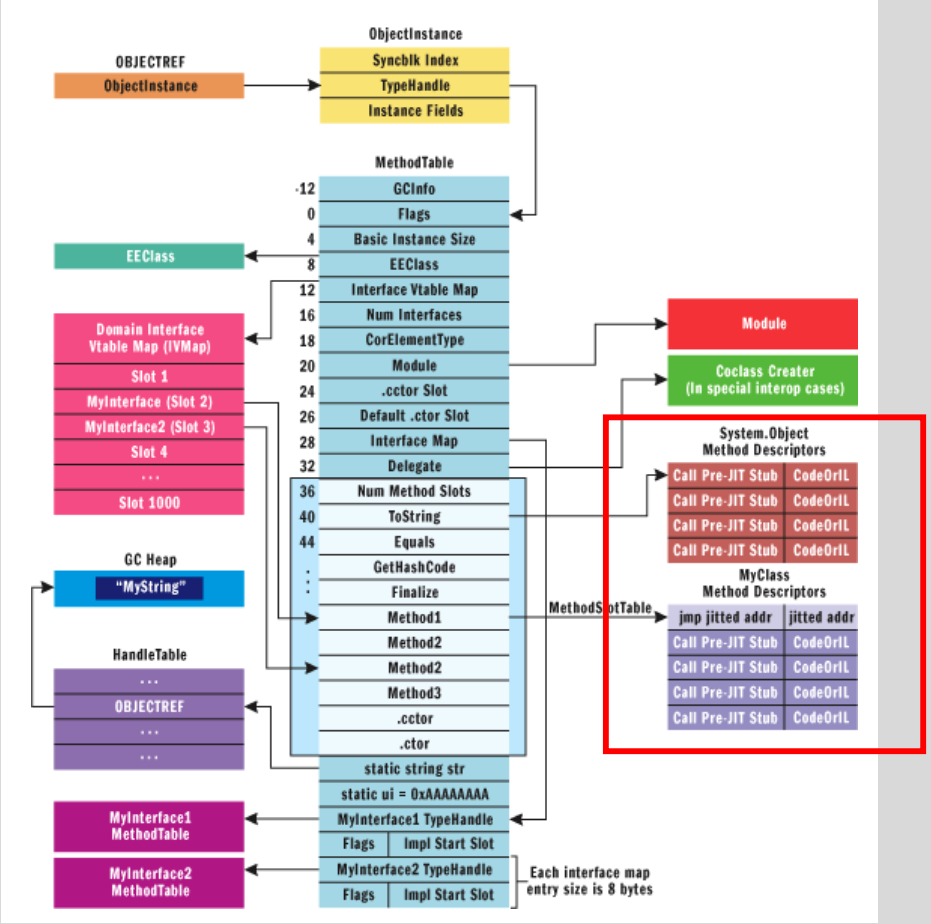
Tools

Telerik Fiddler
Web debugging proxy

Wireshark
Network packet analyzer

Just in Time Compiler

Influencing startup time through the JITer



JIT Compiler

Just in Time Compiler

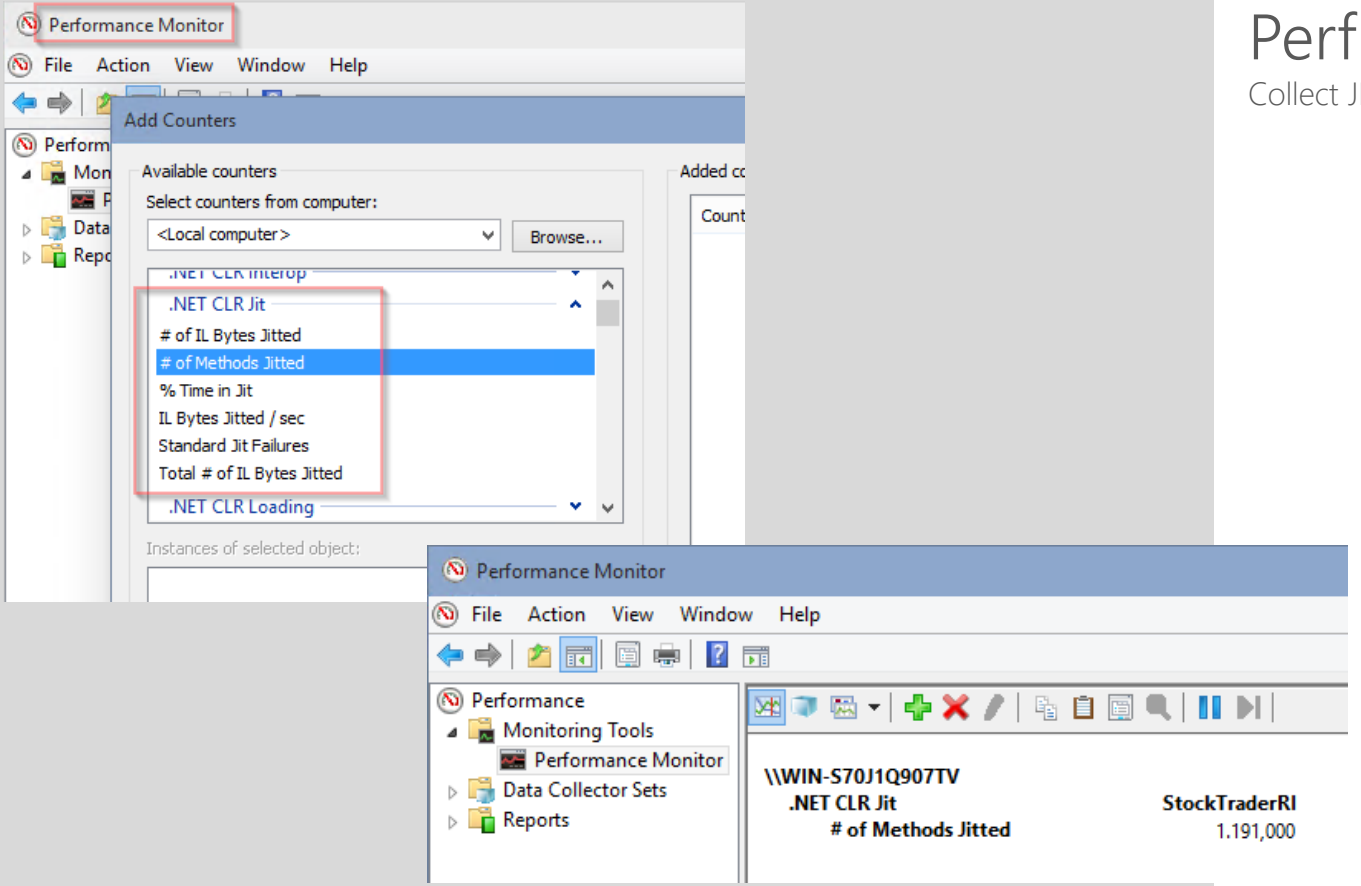
PreJITStub responsible for triggering JIT

Overwritten with a jump to JIT compiled code

Image Source:
https://msdn.microsoft.com/en-us/magazine/cc163791.aspx

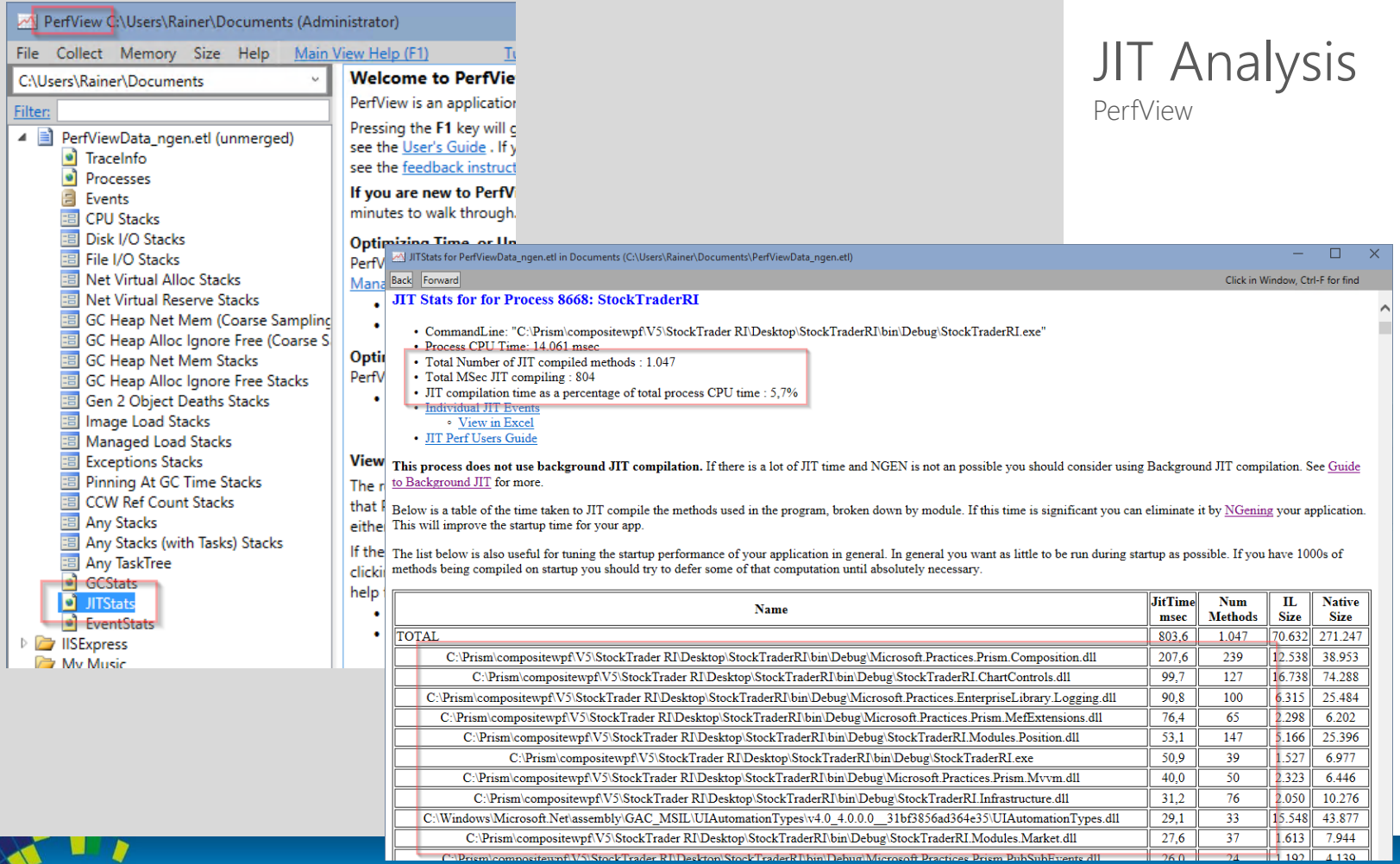
PerfMon

Collect JIT data with PerfMon



JIT Analysis

PerfView



Name	JitTime msec	Num Methods	IL Size	Native Size
TOTAL	803,6	1.047	70.632	271.247
C:\Prism\compositewpf\V5\StockTrader RI\Desktop\StockTraderRI\bin\Debug\Microsoft.Practices.Prism.Composition.dll	207,6	239	12.538	38.953
C:\Prism\compositewpf\V5\StockTrader RI\Desktop\StockTraderRI\bin\Debug\StockTraderRI.ChartControls.dll	99,7	127	16.738	74.288
C:\Prism\compositewpf\V5\StockTrader RI\Desktop\StockTraderRI\bin\Debug\Microsoft.Practices.EnterpriseLibrary.Logging.dll	90,8	100	6.315	25.484
C:\Prism\compositewpf\V5\StockTrader RI\Desktop\StockTraderRI\bin\Debug\Microsoft.Practices.Prism.MefExtensions.dll	76,4	65	2.298	6.202
C:\Prism\compositewpf\V5\StockTrader RI\Desktop\StockTraderRI\bin\Debug\StockTraderRI.Modules.Position.dll	53,1	147	5.166	25.396
C:\Prism\compositewpf\V5\StockTrader RI\Desktop\StockTraderRI\bin\Debug\StockTraderRI.exe	50,9	39	1.527	6.977
C:\Prism\compositewpf\V5\StockTrader RI\Desktop\StockTraderRI\bin\Debug\Microsoft.Practices.Prism.Mvvm.dll	40,0	50	2.323	6.446
C:\Prism\compositewpf\V5\StockTrader RI\Desktop\StockTraderRI\bin\Debug\StockTraderRI.Infrastructure.dll	31,2	76	2.050	10.276
C:\Windows\Microsoft.Net\assembly\GAC_MSIL\UIAutomationTypes\v4.0_4.0.0.0__31bf3856ad364e35\UIAutomationTypes.dll	29,1	33	15.548	43.877
C:\Prism\compositewpf\V5\StockTrader RI\Desktop\StockTraderRI\bin\Debug\StockTraderRI.Modules.Market.dll	27,6	37	1.613	7.944
C:\Prism\compositewpf\V5\StockTrader RI\Desktop\StockTraderRI\bin\Debug\Microsoft.Practices.Prism.PubSubEvents.dll	26,0	24	1.192	4.139

NGEN – Native Image Generator

Generates native images for assembly and dependencies

Reference counting

Advantages

Better startup time (no JITing, faster assembly loading)
Smaller memory footprint (code sharing between processes, important in RDS scenarios)

Disadvantages

NGEN has to be called (also for updates) – requires installer (incl. admin privileges)
NGEN takes time (longer install time)
NGEN images are larger on disk
Native code slightly less performant than JIT'ed code

```
# Display NGEN’ed images
ngen display

# Install assembly
ngen install StockTraderRI.exe

# Uninstall assembly
ngen uninstall StockTraderRI.exe
```

NGEN

Ahead-of-time Compilation

Note that it is important to use the correct version of NGEN

64bit:

c:\Windows\Microsoft.NET\Framework64\v4.0.30319\

32bit:

C:\Windows\Microsoft.NET\Framework\v4.0.30319\

NGEN/JIT Tips

WiX installer framework supports NGEN'ing

How To: NGen Managed Assemblies During Installation

Further optimization with MPGO (.NET 4.5)

Managed Profile Guided Optimization Tool

Generate profile data consumed by NGEN to optimize native images (disk layout)

Opt-in to background JIT (.NET 4.5)

Use System.Runtime.ProfileOptimization class

Garbage Collector

How memory management influences performance

CLR Memory Management

CLR is a stack-based runtime

Value types

Managed heap

Managed by the CLR
Allocating memory is usually very fast
When necessary (e.g. thresholds, memory pressure, etc.), unreferenced memory is freed

Generations of objects

Gen 0, 1, and 2
Large objects (>85k bytes) are handled differently (large object heap)

CLR Memory Management

Different GC strategies

Workstation (background) garbage collection
Server garbage collection (optimized for throughput)
Choose via config setting

Concurrent collection for Gen 2 collections

You can allocate small objects during Gen 2 collection

Background GC

For workstation in .NET >= 4, for server in .NET >= 4.5
For details see MSDN

Memory Management Tips

Avoid allocating unnecessary memory

This would raise GC pressure

Consider weak references for large objects

Reuse large objects

Use memory perf counters for analysis

See MSDN for details

Be careful when inducing GC with *GC.Collect*

Add *GC.Collect* only if you are sure that it makes sense

Memory Management Tips

Hunt memory leaks and remove them

See my memory leak hunting challenge on Codeproject

Suppress GC during perf critical operations

Use GC latency modes for that

Use this feature with care

Summary

Prepare your optimization projects appropriately

Write obvious code first

Measure to find the right places to optimize

Use profilers

Make small steps and gather feedback

Use the cloud