

# Senior Design: Blog Posts

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## 1 Blog Posts

### 1.1 Organization

The following sections contain the blog posts of Nic Desilets and Nathaniel Whitlock. The layout will be listed by order of week for each term of senior design. Since we lost our teammate James Stallkamp, we will not include his blog posts in this submission.

### 1.2 Fall Term

#### 1.2.1 Week Three

##### **Nathaniel:**

The initial meeting of the client went smooth. Our project mentors are Kirby, he has a background in chemical engineering and does a lot of the data analytic work in the team, and Andy, who is an Oracle database administrator. As a team they support the database and provide summary statistics of WebPress performance data.

During the first official week meeting that we had at the HP campus, we were forced to abandon our conference room. The reason was because another group had previously had a reoccurring room booking through Outlook that must have expired and was not re-booked. Since there were more of them than there were us, we fled the room to a end-of-isle cubicle meeting area for an hour. This was a trivial hiccup in the 3 hour meeting, during the rest of the meeting we discussed an overview of the unique "areas" located in a Oracle database instance (ie. PGA and SGA). We also talked a lot about the data dictionary, which is an essential concept in an Oracle system. The data dictionary is a read-only set of tables which provides useful information about the current database instance. Some of the important features of the data dictionary we are interested in is:

- Definitions for each schema object, so every table, view, index, ...
- The amount of space allocated for each schema object and how much it is utilizing
- Information about the users logged in and the privileges they have been granted
- General database information

Most of our group efforts so far have been focused on preparing the Problem Statement document which is due Friday October 14th at noon. After that, each of use will install Oracle 12c on our personal computers. We will be given test data and our goal will be to figure out how to write a toolkit, composed of PL/SQL queries that target a specific table in the database (note sure here, we talked about v\$ and x\$). This will allow us to gather metrics on the server hardware performance after we run a work heavy query.

##### **Nic:**

I had pretty much the same experience as Nathan as we all went to the same meeting and got the same information. We were able to further discuss exactly what our project entails with our clients and got a good understanding of what is expected of us. Our clients also gave us a rundown of their current processes, a little bit of how it works, and what isn't currently working/what we are going to fix. Our goal before our next meeting is to get Oracle 12c installed locally on our machines so that we're ready to dive into it during our next meeting. From there, we will be begin working on further familiarizing ourselves with the database and start developing a toolkit to record metrics on database performance.

#### 1.2.2 Week Four

##### **Nathaniel:**

During our meeting this week we focused on getting Oracle Linux 7 installed on VirtualBox. Once this was accomplished we installed Oracle 12c database software on the VM's so that we could start doing performance related queries targeted at v\$ and x\$. After becoming more familiar with this process we

will begin to put together our performance toolkit that we will use during the rest of the project. Moving forward through the week, I plan on finishing up the installing tasks for my laptop and starting the process of looking at performance states of small queries on my local device.

The toolkit development process will be version controlled through this GitHub repo. We as a team will work on building and modifying things as needed. Additionally, we plan on starting the revision of our Problem Statement after we receive our feedback tomorrow 10/20/2016.

After meeting with our T.A., Jon Dodge, I took his advice of sending James a message. The intent of the message was to let James know the concerns which we are having with his attendance and hopefully persuade him to begin participating with the group more. Hopefully this reaches him in a positive light, I don't want to make enemies with anyone and I surely don't want him to be forced to take another year of school.

This weekend I plan on trying to take a higher level approach to the Problem Statement in order to appeal to a broader audience. The feedback that we received will not take to long to address, then some effort will be put on formatting the final LaTeX document so that we do not lose any easy points.

**Nic:**

Same as last week, Nathan, James, and I generally did the same things at the meeting that we went to. Our goal before attending this meeting was to at least have Oracle Linux 7 installed on a virtual machine so that we would have a development environment to work with. We spent a fair amount of time trying to get Oracle 12c installed onto our machines and have it function correctly. We also discussed how we would gather performance metrics from using our toolkit (one way is to look at the V\$ and X\$ tables within 12c). By the end of the meeting we were mostly setup and ready to start creating the toolkit for the next meeting. Our goal for the next meeting is to actually start this designing and creating this toolkit.

### 1.2.3 Week Five

**Nathaniel:**

On Monday of this week I stayed home due to being ill, but I was able to set aside a lot of time to get my work laptop and personal desktop set up with Oracle Linux 7 workspace set up with Oracle 12c. Getting this set up is essential to moving forward with the toolkit development as well as experimental analysis with the queries in order to get used to writing PL/SQL statements. One of the issues I was having with my work laptop is that when connected from my home network I needed to connect to the HPI network by VPN, before doing this I had no network activity through the VM.

**Nic:**

Earlier in the week I worked on the problem statement a little bit to remove some of the technical jargon and make it more generally accessible. I also got a start on the requirements document towards the end of the week. Aside from papers, I finally got Oracle 12c configured properly with Oracle Linux 7. Next week we should be able to start building our toolkit.

### 1.2.4 Week Six

**Nathaniel:**

Tuesday evening I spent time working on the Requirements Document as well as spent some time getting used to running queries on my VM. Some problems that I have run into include hunting for formatting options for LaTeX. Though I am familiar with getting a basic document laid out in LaTeX, there is a huge amount of scripting functions that exist and sometimes it can be a pain finding examples and then isolating the part that you need. One of the sources which has been extremely helpful is the, "Not So Short Introduction to LaTeX".

It was hard for each of us to find time to work on the Requirements Document at the same time, but as of Friday morning we finished up a working version of the document. There are so many sections that seem redundant so there is a sense of repetition through the document.

Problems that I faced this week were in formatting the LaTeX output. I was trying to force formatting on the document to fit the picture I had in my mind, however, trying to override the IEEEtran.cls defaults was causing nothing but trouble. Luckily, our T.A. Jon Dodge was quick to respond to an email that I sent out Thursday evening. He mentioned that looking through the .cls file for areas of the code that pertain to a specific element you are trying to modify (ie. section, subsection, etc.) and see what is available through the class options. I was trying to force the subsection headings to have arabic values when they had alpha characters, the method I was using was something I found on stackoverflow and I should not have tried to use it without understanding the effects. Thanks to Jon I will be looking

through .cls files for formatting commands.

Moving forward we will be reading The Oracle Optimizer Explain the Explain Plan. This should give us a basic understanding of sorting and merge operations within the database environment so that we can build on some hands on examples with Andy next week.

**Nic:**

As mentioned earlier, it was difficult to find for all of us to work together on the requirements document which was a pretty big undertaking of it's own due to the complexity of the document. Personally, I was busy with a midterm from another class that coincided with the due date of the requirements document so I was unable to devote a whole lot of time to it. Some progress that I did manage to make this week was to setup a Slack channel for all of us, including our clients, in hopes of being able to establish a better means of communications for when we need a place to all discuss things and collaborate concurrently. Email and texting is generally sufficient but sometimes an instant messaging service is more convenient. I was also able to help a little bit with the requirements document earlier in the week. Going forward, I need to go over the paper that Nathan linked above in order to gain a better understanding of how Oracle 12c sets up execution plans when it receives queries. Knowing this will aid in developing the toolkit that we need to create in order to measure performance of queries.

### 1.2.5 Week Seven

**Nathaniel:**

This morning I finished up reading the Oracle white paper called "Explaining the Explain Plan". It was an insightful document that discussed methods of viewing a list of estimated procedural steps the database optimizer will perform during query execution. This can be a helpful tool to use in order to gauge the efficiency of the optimizer and/or where some specific bottlenecks in the processing may be.

This morning I ran into an issue remembering what password I set up for the sys user profile within the 12c environment in my VM. I was not sure if it was set to something default because we were not worried about security, but it turned out I made the password the same as the oracle OS user account password. After getting that squared away I was able to use a SQL script provided by Kirby Sand to generate fake data. The next step we should focus on is identifying the various tables within the V\$ view. After we locate the tables which contain performance results, we can start developing the performance analysis toolkit.

**Nic:**

Progress: The primary task for this week was to read Explain the Explain Plan which describes how the database optimizer breaks down and processes queries. This document contains a lot of important information and will prove useful later on when we get to configuring the database to perform more optimally for our given data sets. At our meeting on Wednesday we were all given a script which will generate a data set for us to work with in the future.

Next Week: Our plans for next week will be to continue to read and understand how the database optimizer works. Additionally, we should also become more familiar with all the V\$ and X\$ tables within the database. These tables are what hold all the information that we will need for generating performance metrics.

Problems: I do not recall running into any significant problems this week.

### 1.2.6 Week Eight

**Nathaniel:**

Last night was Sunday 11/13/2016, I spent most of the afternoon and evening finalizing my section of the technical review as well as the introduction, abstract and general document formatting. I spent additional time citing each of the web based sources that I used in IEEE citation format. It appears that the document which is due today, Monday 11/14/2016, only needs to be a draft. I know that this has been the case with our other documents, however, I assumed that we should be moving away from that option. If all that is due is a draft, then I am feeling good about my section. Before it is turned in tonight by midnight, I would like to do the following:

- Mention in the conclusion why PostgreSQL and Redshift were not chosen. This could mention that Redshift did not support many of the modern features from updated versions of PostgreSQL. Also, mention something about the recent update for PostgreSQL that attempted to patch a data corruption issue (That would not be good for a corporate environment).
- Decide whether or not to scrap the Introduction section. The abstract can probably serve as a document outline, as well as the table of contents. However, it would still be good to have a global

conclusion or something.

We were able to finish and clean up the Tech Review document, and I feel that we will do well on it overall. It was refreshing to see that we got another A grade on a large paper (Requirements Document). Since we had class cancelled on Thursday, I made a brainstorm list of design based choices that would dictate our groups path forward in terms of manipulating parallelism and partitioning related setting in the Oracle environment. There were no specific problems which were experienced during this week.

**Nic:**

Most of the beginning of the week was spent working on the tech review making sure that it was complete and that all the assignment requirements were appropriately met. Our weekly meeting with our client went well and felt much more productive than past meetings since we weren't bogged down with getting input on yet another writing assignment. We were able to start getting acquainted with the V\$ tables in the database and start getting basic metrics such as database time and wall clock time for a particular query. I do not recall running into any significant problems this week.

### **1.2.7 Week Nine**

**Nathaniel:**

This week we did not encounter any problems. During our meeting with our clients we were able to work on my queries on the dynamic performance view table within our Oracle instance. It was nice to have Andy back from hunting so we could ask his questions.

Moving forward we need to begin focusing on the design document. It is difficult to get started, even by consulting the IEEE document, this assignment seems very repetitive. Since we have a research based project, it is hard to plan out the entire design phase because we are not sure what direction we will be taking after the next couple weeks of thorough research.

Hopefully we will be able to finish through the documents we need to write this term and then transition nicely into the SQL tool development. As of now, I am not sure how well this will work out.

**Nic:**

Problems: Our main problem was just getting a start on the design document since it did not seem to fit our project very well. The IEEE document that we were to base our design document off of had a lot of content and expectations in it for a simple .zip folder of SQL queries for performance monitoring.

Progress: We made some progress during our meetings with our client by working with some more of the V\$ tables within Oracle 12c. These will come in handy later on when developing the toolkit.

Plan: Our plan for the week is to continue working on the design document.

### **1.2.8 Week Ten**

**Nathaniel:**

Progress: We started focusing on the topic of tracing a query. It is basically a process that documents the processing decisions in a log file. This can be used to generate additional statistics about file I/O and other useful metrics. We were able to get the design document done, but we were not able to get signatures, that will be taken care of Monday of finals week.

Problems: The design document was pretty difficult to finish. I was having a hard time generating content for some of the design viewpoint sections. It is nice that the design document was the last technical writing assignment for a while.

Plan: Moving forward we will be focusing on the progress report and presentation. Since all that we have done is write papers, the paper will likely be pretty boring. In terms of development, I think we are going to focus more on tracing.

**Nic:**

Progress: This week primarily consisted of working on the design document and getting it finished up. In our meeting with our clients this week we were introduced to tracing which is another method of monitoring database performance. Tracing involves turning on certain parameters in the database to enable verbose logging of different levels of activity depending on which parameters were enabled. Oracle 12c was designed from the ground up with logging in mind so tracing is a very powerful tool for monitoring what exactly the database is doing in addition to the built in performance tables.

Problems: We did not really have any new problems this week. We continued to struggle with creating the design document but we were able to get it done in time.

Plan: The plan for now is to begin compiling our blog entries into our progress reports. After this is done, we are planning on creating a presentation from the compiled progress report.

### 1.3 Winter Break

#### **Nathaniel:**

During the break most of my efforts were spent on implementing trace functionality within our toolkit app. Additionally, I set up an external tablespace within the Oracle DB that launches a preprocessor script that runs the recent tracefile through a summary tool called tkprof, the result can then be queried. The plan is to use the summarized output to display a diagnostic report within the toolkit app interface.

More work was done that focused on how we can make stored procedures available to the app, options considered include:

- Storing the procedures on the remote file system in a specific directory for utilities
- Create stored procedures that can be executed from the query workspace

We meet with the client one time during break, and all the work that was done in terms of development and research was done remotely. Now that winter term has started, our team needs to hit the ground running. Our clients will be giving a presentation at an Oracle convention in Texas during the window of February 27th to March 2nd. They plan on using some of the research that we have provided during the presentation, we also need to provide quantitative evidence of different system configurations.

Problems: Some of the major problems that I dealt with during break included:

- Issues with JS asynchronous callbacks and wrapping a trace wrapper around the user query
- Figuring out a way to move all the tracefiles from one session into a specific directory and giving the summary a unique stamp
- Figuring out how to use the external tablespace concept to help us display reports to the user

Progress: All of the issues that were run into were resolved. In the current state, the user can submit a query, choose optional trace event codes, and select from a list of performance metrics. The output needs to be reformatted so that each desirable result can be displaying in a dashboard style.

Plan: Moving forward, we are not going to be spending any more time on developing the toolkit app. All efforts will be placed on initial research of configurable parameters that may help optimize PGA usage, in turn reducing the need to swap to temp. These parameters will then be adjusted and the runtime analysis will be used to quantify the improvements from the base configuration with default values.

In terms of the toolkit app, we need to consider:

- Preventing malicious SQL execution (ie. reject DROP/INSERT/UPDATE clauses)
- Update the results page to better display the final output, including the diagnostic reports and statistics
- Move procedures to server file system, or create stored procedures within the DB that can be called from the SQL workspace

#### **Nic:**

Progress: At the beginning of Winter break we had met with our clients at HP to discuss topics to research and focus on over the break. I also showed our clients the beginnings of our toolkit that we were going to create as part of our deliverable. Our main area of interest over break was to experiment and get familiar with the various trace events within the database. These trace events will be useful to us in our research since they help detail how the database makes decisions internally when it comes to executing user queries. We were thinking of integrating trace event functionality into the toolkit to facilitate obtaining trace results. Near the end of the meeting I had an idea to help temporarily alleviate the issue of excessive temporary table usage (swapping to disk) for certain types of queries.

I spent the first half of Winter break mostly focusing on making progress in our toolkit and also experimenting with a ramdisk for the database. The ramdisk that I created was to be used for the temp tablespace for the database. The temp tablespace is what is used for when the individual database server processes run out of memory and so they can essentially swap to disk by swapping to the temp

tablespace. My idea was to move the temp tablespace off disk and into memory by using a ramdisk as a stopgap solution until we find the real solution through experimenting with internal database parameters. This idea proved to be very effective in improving response time for queries which originally spent a large portion of time swapping to and from temp.

Later on in the break it was determined that we should stop focusing on the toolkit and to really start focusing on database research. This is primarily because our clients are going to be presenting our collective findings (between us and our clients) at an Oracle convention by the end of February. This only leaves us a little less than two months to figure out why the database isn't performing optimally, document our solutions, and create publically reproducible test cases.

Problems: I had some problems with the toolkit early on, mainly stemming from some design issues. Originally the toolkit that I created was meant to be a quick demo and so naturally some aspects of it were rushed and looked over. My primary problem with the toolkit was the server returning non-descriptive results which were displayed in a hard-coded fashion in the actual web application. I fixed this by redesigning how the server returns results back to the web interface so that it is more generalized. The server can now return named datasets each containing some metadata on how the results should be processed and shown to the user. However, after we decided to halt progress on the toolkit, our main problem is now time and the fact that we still don't really know how the database works internally.

Plan: The plan now (as of the end of Winter break) is to focus on figuring out how the database works so that we can tune it to perform more optimally for our client. Some key research points will be figuring out how parallelism works, how database processes use memory, and how to best optimize these two.

## 1.4 Winter Term

### 1.4.1 Week One

#### Nathaniel:

This week we focused on breaking our research efforts into a few high level questions, the three we came up with Wednesday were:

- How is the DOP of a query executions actually determined? (James)
- Explain the relationship of the PGA and its sub-components. (Nic)
- Figure out how to extract clear diagnostic information from a query. (Me)

Problems: There are two trace event codes 10390 and 10391 that generate run time information about parallel processing. Since the system we are working on nearly always runs in parallel, it is important to try to extrapolate this info so that it can be used to validate our run time model between the PGA use, wall time, and DB time. Though I have been able to successfully generate reports for many of the other trace event codes, 10390/391 has it's levels of granularity expressed in hex, where all of the others are expressed in decimal. One of my tasks was to profile all of the individual levels of both problematic trace events. I ran into major issues getting output files from the trace request.

Progress: In order to try and resolve this I converted the hex values to decimal and tried that. The other available trace event codes have a flagged numbering system that resolves to a decimal. A value of 0 is basically off, 1 value initializes the trace, a 2 value sometimes adds a layer of complexity, and 12 value run both of the previous layers. This is not something that I am giving up on, but it is been a major pain.

Plans: Plans going forward will be to finish reading the Oracle whitepaper on parallel execution, the goal is to pull out some important factoids that Kirby and Andy can use in their presentation. Also, I want to experiment with the query that Kirby put together to grab run time statistics from a query. Then I would like to make a couple parameters of choice and run then at various values to track the effect on the query performance, the initialization parameters we are most interested are:

- `_pga_max_size`
- `_smm_max_size`
- `_smm_px_max_size`

and possibly:

- `sort_area_size`
- `hash_area_size`

**Nic:**

Progress: We met twice with our clients during our first week of the term. During our first meeting, we had a discussion on what we all did over the break and presented our findings. We also more formally went over our overall research plan and broke it up into areas that were assigned to each of us (mentioned by Nathaniel above). I was assigned to documenting and creating visual diagrams of the PGA and its relationships with its various subcomponents.

In between our two meeting we all did some beginning research on our respective topics. I was able to document the components within the PGA and identify some internal database parameters that govern them. We each presented our findings during the second meeting. By the end of the second meeting we came up with a list of parameters to focus on that were related to PGA.

These parameters are:

- PGA\_AGGREGATE\_LIMIT
- PGA\_AGGREGATE\_TARGET
- \_PGA\_MAX\_SIZE
- \_SMM\_MAX\_SIZE
- \_SMM\_PX\_MA\_SIZE

Problems: My primary problem with my assigned area was I was at first a little unsure of the exact requirements of what I was supposed to be doing (as in how to create the diagrams and such) after the end of the first meeting. This turned out to be a non-issue after confirming my results with our clients during the second meeting. The main issue now is still the fact that we don't have much time left to get this all figured out, but at least we have a better idea of what to focus on now.

Plan: The plan now is to further explore the relationship between PGA and its subcomponents and also experiment with the parameters above. I hope to have some material ready for our next meeting detailing how the parameters affect the subcomponents within the PGA and ultimately how they affect performance.

#### 1.4.2 Week Two

**Nathaniel:**

During this week we had our first T.A. meeting for the term. I brought up the fact that our efforts will be focused on research rather than actual product development. Jon Dodge, our T.A., requested that we get an email from our clients that outline the fact that they don't expect us to deliver them a software product, rather, they want us to put together a presentation with them and produce experimental evidence that supports our claims. After telling Kirby about this, he was happy to send out the email.

This week was somewhat slow. I read through Oracle documentation on Parallelism and Partitioning as well as looked through info on credible Oracle Ace or Oak Table sites. These sites are hosted by individuals with paid or non-paid support from the Oracle company.

Problems: One problem that I ran into was getting false positives for 10390 391 trace events. I tried to wrap a series of trace headers around a query in hopes to generate series of different output, however, the 10046 output was just spread through the neighboring results. Also, on January 11th I had set an initialization parameter, Memory\_Max, to a size larger than the available resources. In light of this, once the database was shutdown it would not start back up. Andy, one of our mentors at HP was able to help me get the issue resolved.

Progress: This week I made a graph that outlines that effect setting pga\_aggregate\_target has on the \_pga\_max\_size, \_smm\_max\_size, and \_smm\_px\_max\_size parameters. Though this graph, we were able to derive formulas for how the later three parameters are calculated. This gives us a glimpse on what the desired ratio is in the native Oracle 12c setup.

Plans: Going forward I will be writing two scripts, one that will reset the DB parameters back to the desired baseline values, and another that prompts the user for input. The latter script might be constructed first with substitution variables, but also I might make a command line version that will just accept a series of arguments.

**Nic:**

Progress: This week I was primarily focusing on cleaning up the slides that I had prepared last week. I was tasked with updating them with our newly found information regarding PGA parameters that Nate

had found specifically for Oracle 12.1c. I was also adjusting the coloring a little so that the colors of certain elements were more consistent from slide to slide (e.g. if something is colored red on one slide, that same thing should still be red on the next slide).

Additionally, I started looking into In-Memory Parallel Execution more to get a better idea of how to better set up the database to take advantage of parallel execution without having to resort to swapping to memory (which is a problem at the moment). I was able to find out some parallel execution related parameters that govern whether or not In-Memory Parallel Execution is used. Since I was on that topic I decided to look into other parallel parameters that determine additional parallel execution properties.

Problems: I do not recall encountering any significant problems this week.

Plans: Our plans for next week are primarily to determine how the System Global Area (SGA) works within the database and also how it is used for parallel execution. I will probably get some slides set up detailing the components within SGA.

### 1.4.3 Week Three

#### Nathaniel:

This weekend I read through the Oracle whitepaper on In-Memory. Many of the insights and notes that were taken have been placed in our OneNote workbook.

Problems: There were no major problems that I encountered this week.

Progress: Initial research was completed on the topics that will be the focus of experimentation during week 4. As stated above, the notes taken from the research process have been documented on the OneNote workbook.

Plans: Next week I would like to begin some targeted experimentation to test if we can exercise the benefits of In-Memory storage (or In-Memory Parallel Execution). Additionally, it would be nice to experiment with Automatic Big Table Caching.

#### Nic:

Progress: I spent some time detailing the various components in the SGA in order to identify which components are involved in parallel query processing. One of the components of the SGA that stands out is the Database Cache which contains individual caches for blocks of data based on block size, as well as an optional Big Table Cache. The Big Table Cache can store entire tables and partitions rather than individual blocks. Additionally, I read more into the In-Memory Column Store and performed some testing on that. At first my results were inconclusive and using the In-Memory Column Store did not seem to offer any performance benefits. However, after testing different schemas and queries I was able to get about a 60% performance increase in my preliminary testing.

Problems: I don't recall any significant problems other than initially not seeing any performance increases with the In-Memory Column Store.

Plans: The plans for next week are to hopefully get some early slides made for SGA and continue testing the In-Memory Column Store.

### 1.4.4 Week Four

#### Nathaniel:

This week I spent a lot of time reading through In-Memory white papers from Oracle, links to both papers can be found below. My focus was on gaining an understanding of how Oracle 12c In-Memory works under the hood. Besides gaining a basic understanding of how In-Memory works, I also focused on identifying areas to experiment with for potential performance gains.

- In-Memory Overview
- When to use In-Memory

During our Friday meeting we were asked to put together a series of scripts that would facilitate a test suite and resource monitor package. Andy outlined what he had in mind on the board, I started trying to implement his vision with shell scripts and Nic began developing in node.js. By the end of the meeting we both had a basic working system.

Problems: The main problems that I ran into were in getting an initial connection set up to the capstone database with bash. After a bit of troubleshooting the problem was resolved.



Progress: By the end of the meeting I had a three scripts put together driver.sh, runMonitor.sh, and runTest.sh.

- driver.sh: Prepares the environment and calls the two run scripts
- runMonitor.sh: Establishes connection to capstone server and executes resource monitor package loop
- runTest.sh: Establishes connection to capstone server and executes test suite

On Saturday I spent more time cleaning up and commenting what I had originally. I also set up an issue in the issue tracker that outlines my To Do list for this script.

Plans: I plan on getting feedback from the group and our mentors. These test facilitators will be used to run nightly tests to gather data we will use to validate our performance goals/claims.

#### **Nic:**

Progress: Read up some on how our queries could potentially benefit from enabling the In-Memory Column Store. The primary advantages are that the IMCS format is optimized to take advantage of SIMD vector processing which allows the CPU to perform operations on multiple values at once (similar to a GPU, but much smaller scale). The most often used columns within the most commonly accessed tables could be set into the IMCS and offer us better query performance. I have done some preliminary testing that showed about 60% of an improvement in query response time when enabling the IMCS for a particular table and query. During our last meeting of the week I got the development server at HP setup with NGINX and NodeJS in order to host our web based toolkit. My plan is to have the web based toolkit wrap around and utilize Nathan's bash and SQL scripts.

Problems: Did not encounter significant problems this week, other than initially having some trouble getting HP's development server setup with NGINX and NodeJS. The server sits behind a proxy which I was not initially aware of, so that caused issues with trying to download anything until I specified the correct proxy to use.

Plans: My plan for now is to put a bit more work into the web based toolkit and then we will probably all start focusing on testing SQL query performance with varying database configurations.

### **1.4.5 Week Five**

#### **Nathaniel:**

This week most of my focus was place on implementing the series of shell scripts that work together to facilitate test suites that will be run during the evening. We will be using this tool to run nightly experiments in the following three experiments:

- PGA Experiment: Focused on altering the values of '`_pga_max_size`' and monitoring the potential spill over to temp during operations such as sort, hash, and window sort
- Big Table Cache Experiment: Focused on altering the percentage of the buffer cache that caches large objects in memory and monitoring potential read performance
- In-Memory Experiment: Focused on enabling In-Memory column store and monitoring the potential performance improvements

Problems: The problems that surfaced this week included the initial version of the test automation scripts ended up not working as planned. One connection is established to run a monitoring loop in the background, when another connection is established and the command is issued to close the pluggable database the monitoring loop was terminated.

Progress: During the meeting we talked about the logic needed to resolve this problem and began modularizing the sql experiment scripts so that they can be run in two phases: if there is a parameter file then run that in a separate connection, run sql file.

Plans: My plans moving forward are to finish and test the test automation script and run all three experiments before Monday so that we can look at the data during the meeting Wednesday during the meeting. The data must be graphed and prepared before that time as well.

#### **Nic:**

Problems: No significant problems for me personally, however as a group we ran into issues with previously ran tests where we were getting some unexpected results (ex: enabling features to increase performance

sometimes led to sharp unexpected decreases in performance or no improvements at all).

**Progress:** This week I primarily worked with Nathaniel a little bit to help get the script working in some parts. I also refactored one of our tests (IMCS) to fit a newer more modular format to work with the updated testing script. As the team captain I also got the expo registration details sorted out.

**Plans:** I don't have any immediate plans as of this moment, however as a group our plan is to continue creating, performing, and analyzing tests using our test automation script. After we look over the results of the IMCS test we will probably end up devising further tests to test both the IMCS and Big Table Cache concurrently (since they are designed to work in tandem with each other). Right now we are only testing them separately to help gauge their individual effects before we start looking at their combined effects.

#### **1.4.6 Week Six**

##### **Nathaniel:**

This week we were able to get all three of our experimental suites to run and collect valid data on all of them. I also spent time troubleshooting the test automation scripts as well as make slides that detail the memory pools within the In-Memory column store.

**Problems:** Early in the week we ran into issues getting the IMCS experiment to run correctly. During our meeting on Friday we condensed the directory of parameter and sql files into three total files, one parameter file and two sql files. It turned out that all four of the experimental tables could not fit in the IMCS when it was set at 192G and the objects were flagged as NO MEMCOMPRESS.

**Progress:** Sunday evening I finished up the rough draft of my IMCS pool slides and also made a couple of graphs that detail the effects of the six different compression levels offered in Oracle 12c. Additionally, I made a graph that shows the compression ratio for each of the four experimental tables.

**Plans:** Moving forward Nic and I will be helping Kirby and Andy prepare anything else they need to make the presentation go smoothly. This will likely include generating more slides on the topics we experimented on, as well as some additional experimentation.

##### **Nic:**

**Problems:** We had some issues with our script where the column store did not finish completing before any other scripts were ran.

**Progress:** This week we were mainly focused on completing the IMCS test and making sure that the column store was being populated before the IMCS tests were ran.

**Plans:** Our plan is to get the IMCS test finalized over the weekend, and then from there we can focus on creating some more slides. We are nearing the end of the critical point of our project and so really we just need to finalize everything (mainly presentation details). I'm going to focus on vector processing for slides.

#### **1.4.7 Week Seven**

##### **Nathaniel:**

This week our clients were in Austin Texas at an Oracle convention, while at this event they gave an hour long presentation that outlined the experimental research that we have been working on. Tuesday evening I got a phone call from Kirby saying that the presentation went really well and they were asked to come back again next year.

Nic and I still met on Wednesday for three hours and Friday for two, in order to work on our Design Document and begin writing up our progress report. This will be the mid point progress report that will outline the end of Fall term to week seven.

**Problems:** There were not any significant problems this week, rather, after beginning to work though the documentation it became clear that it was written in a way generalized enough that it still fits that scope of our project; therefore, we will only need to make minor adjustments.

**Problems:** The only problem that we ran into this week was in getting the statement queuing experiment to run correctly. There was some confusion on exactly what to modify within the design document, after reading through it there were only a handful of modifications that were needed.

Progress: The revisions that were made on the Design Document were sent to Jon Dodge towards the end of the working meeting that Nic and I had Wednesday, this should take care of the revisions that we needed to do for our fall documentation. Friday we made bulleted lists in our OneNote that outline our progress up until week seven. Now the plan is to formalize the timeline so that we can submit it.

**Nic:**

Problems: No problems this week.

Progress: Our clients had given their presentation at HOTSOS and it went well. We did not meet this week with our clients and so not much progress was made since we more or less had this week "off." Nathan and I had met to finish up working on our document revisions now that we had time to focus on that.

Plans: Finish up documentation revisions.

#### **1.4.8 Week Eight**

**Nathaniel:**

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Plans: Finish up documentation revisions.

#### **1.4.9 Week Nine**

**Nathaniel:**

This week we started looking into two new features of interest for the clients, indexing and partitioning strategies. Our clients are experiencing slow DML operations during the nightly job. Approximately every seven days, a table called the data loader dumps its contents into a table called data reader. Data reader can be a 500GB compressed table with 500GB of indices. The problem is that inserts into an indexed table are extremely costly due to all of the write operations to the redo and undo tables. A rule of thumb is that for a table with two column index, an insert that would take a single instruction will take four on an indexed table, thus the root of the problem.

Problems: The only problems that I ran into this week were in figuring out a reasonable way to try to simulated the data loader and data reader tables within our test environment. I also am still not entirely clear on how many columns in the data reader table are indexed, as each additional index adds a cost factor.

Progress: I have created a data loader and data reader table, the data loader table has all rows from device id 17 from the last two months, and the data reader table had the remaining four months. Based on this quick and dirty experiment, I was able to observe the cost of inserts on an indexed table.

Plans: Moving forward, I need to make sure I have a solid dataset prepared by Wednesday. Emphasis needs to be placed on getting a primary key relationship between the device id and timestamp, however, since our data was randomly generated with a tight range of values one could not be set up initially due to non unique entries.

**Nic:**

Progress: With the presentation over with and bulk of our research done, we decided to keep on researching more aspects of the database that could further improve data performance for our clients' nightly jobs. Since the tables involved are very large and thus have very large indexes, it takes a while to insert new records into the database (part of the reason is maintaining these indexes). Two of the key areas that we are going to focus on now are partitioning and indexing in the context of bulk inserts (from nightly jobs) on very large tables.

Problems: The main problem that we are focusing on now is how to alleviate performance problems associated with bulk inserts on very large indexed tables.

Plans: My plan is to research database partitioning and try to figure out an optimal way to partition the data. Right now the debate is partition by date and subpartition by device id and vice versa.

#### **1.4.10 Week Ten**

**Nathaniel:**

Most of our efforts this week have been placed on getting our progress reports and poster together for finals. I have not continued setting up the index experiment because I have a lot of overhead with finals this week, once I am done with my exams on Tuesday I will start up again.

Problems: No major problems were encountered this week.

Progress: Our poster rough draft came together quite well. Some of the working will need to be carefully read through and made more succinct.

Plans: Moving forward, I plan on focusing on finals until Tuesday evening, then I will start up on the index experiment again as well as finish my progress report for CS 462.

**Nic:**

Problems: The problem for my portion of research is still whether or not we should be partitioning by date and then subpartition by device id or partition by device id and subpartition by date. So far we know that the bulk inserts portion of the nightly job would favor one partitioning scheme while the nightly aggregation portion would benefit from the other. Overall, we are looking for the best solution and compromise to suit both.

Progress: This week we had put together and submitted the draft for our poster. We were able to get most of the details that we wanted to in the poster, minus the final results section since we technically still aren't done with our research now that we have started exploring more options. Similar to Nathan I have been busy with finals, mainly with other final projects, that are due at the end weekend of Week 10 and so I haven't had a whole lot of time to devote to research recently. I have made some headway on partitioning over the past couple weeks but not as much as I would like.

Plans: My focus for now is to get my finals out of the way and then I will have more time to dedicated to researching partitioning.

### **1.5 Spring Term**

#### **1.5.1 Week One**

**Nathaniel:**

Most of my efforts this week were focused on transitioning back into school responsibilities. After working more than 40 hours over break, it took some time to switch gears. There was not much done on the project during spring break and we only had a single meeting with our mentors.

Problems: There were no problems during this period.

Progress: There were no obligations during the break, therefore no true progress was made.

Plans: Moving forward I plan on writing up four different experiments that leverage the partitioning strategies that Nic has put together and apply the indexing experiments to each. The indexing strategies I am looking into are:

- Global index
- Local index (Prefix/Non-prefix)

Also, I plan on looking into the effect of different sizes data loaded into the main table (ie. 2%, 5%, 10%) and look into overlapping data that exists in both tables to observe the effect it has on weekly load performance.

**Nic:**

Problems: We did not officially setup a meeting time for this week and so we did not meet this week. Because of this, we didn't get much done.

Progress: Not much progress was made for me this week.

Plans: Meet next week and go from there.

### 1.5.2 Week Two

**Nathaniel:**

This week most of our efforts were focused on finishing the experiments focused on indexing and partitioning strategies. The initial design of experiment that we put together has been complexified by our clients, they would also like us to focus on the different methods of uploading overlapping data.

Problems: The only issues that I ran into this week was not having enough memory on our test server to create the two billion record table that our clients requested. It seems like the issue is a physical memory limitation, rather than a disk space issue.

Progress: During the terminal weekend for this period I spent quite a bit of time writing up the indexing experiments for each of the unique partitioning strategies, which were put together by Nic. I was able to run quick and dirty experiments to log the runtime of the different configurations, however, I will need to configure the resource monitor package to track the data points I am interested in monitoring for these experiments.

Plans: Going forward, I plan on altering the resource monitoring loop and completing the modifications requested by our mentors to the four scripts which represent the different partition strategies that we will be evaluating.

**Nic:**

Problems: I do not recall running into any significant issues this week.

Progress: Nathan has been doing most of the work involving the script to test our experiments. I started to look into clustering to cluster related blocks of data together on disk. There are options to cluster based on columns or join conditions. Additionally blocks can be clustered linearly with each other or interleaved in a zig-zag type order. However, I feel like that would add too many dimensions to our test script and potentially go beyond our scope, especially since we only have a couple weeks left for "development" until the code freeze before expo.

Plans: We have our testing plan (what we're testing) more or less complete, now we just need to focus on the monitoring script so that we can gather the relevant data that we need to evaluate the performance of our options.

### 1.5.3 Week Three

**Nathaniel:**

This week we spent time working on cleaning up the content in our poster. One of the major changes we made was writing the intro to be more succinct. We still need to wrap up the conclusion and get a picture of us, as well as get a signature from our clients.

Problems: No issues were encountered during this period.

Progress: The last draft of the poster we submitted was also sent to our clients so that they have ample time to look over and suggest any changes. We still need to talk with them about an approved company logo.

Plans: Moving forward I plan on finishing the indexing and partitioning experiments Nic and I put together and collect the results of the database and wall time it took for DML operations. Monday at our meeting Nic and I will get a picture together for the poster, and I will ask Kirby about a company logo. We will likely spend some time finishing up the parts of the poster that still needs work.

**Nic:**

Problems: No big issues during this week other than fixing a small mistake I made in one of the sub-partitioning schemes. Originally I had a table partitioned by device id and then subpartitioned by date using hash buckets which didn't make sense. I fixed this so that the dates were subpartitioned into a predefined list of days spanning from the oldest timestamp to newest timestamp. This should be a much more effective partitioning scheme.

Progress: Aside from fixing one of the partitioning schemes, we mainly just worked on the poster this week to clean some areas of it. The introduction of the poster was a little verbose so we tried to shorten it down some. We also sent the poster to our clients for feedback.

Plans: Plans for next week are to start working on a simple web app that we can use at Expo to help visualize some of our experiments. Also we still need to get a picture for our expo poster and finalize the poster before 4/28.

#### 1.5.4 Week Four

**Nathaniel:**

This week, I worked on finalizing the series of experiments designed to look at the run time of inserting a 10 million row table into a 200 million row table. The goal is to see how different indexing and partitioning strategies effect performance, in hopes to figure out the most appropriate method of inserts for nightly job performance.

Problems: I began setting up this series of scripts like we had set up the initial experiments (ie. PGA, BT Cache, and IMCS), however, the scripts quickly became to long and likely prone to human introduced error. In order to resolve this I made additional scripts to contain only the various tests I needed to run. Six scripts were needed, the first three for when the data loader table has only rows not existing in data reader, and the other three for overlapping data in data loader which already exists in data reader. The purpose of the test types are defined below:

- No or Non-unique index
- Prefix as date for unique and primary key
- Prefix as ID for unique and primary key

Progress: Friday morning at 12:21am I started up the test automation suite and began executing the index experiments on the server at HP. I confirmed that the resource monitoring loop was writing run time data from the experiment to our collections tables. The experiment completed at 7:15pm, if all the tests completed without any syntax errors the entire experiment took nearly 19 hours to complete.

Plans: Going forward I need to confirm there were no issues with any of the tests which were run, which can be done by comparing the number of entries in the data collection tables to the number of tests which should have completed. Also, I will begin gathering data so that we can visualize the results.

**Nic:**

Problems: No significant problems this week.

Progress: Started working on a web based visualization tool that serves as an extension to our poster for our Expo presentation. It's something that is outside the scope of our project but would be nice to have. The idea is that we can use it to further elaborate on the experiments that are mentioned on our poster. For each test there will be a description that briefly describes the experiment and also any associated graphs to help visualize the results.

Plans: In our next meeting with our clients we will hopefully have some time to go over what information and graphs we want to show for each test. Once those aspects are decided it should not take long to get the web app completed.

### 1.5.5 Week Five

#### **Nathaniel:**

This week we delivered the results of the index/partitioning experiments that Nic and I put together. Kirby was happy with what he saw from the initial evaluation of the results, however, there still might need to be some general house keeping steps before we can be done with that.

Problems: One of these module names for overlapping data was mislabeled as standard query, though it was using a no duplicates hint. This is not a huge issue, as the no duplicate queries were also run in the named section, but rather it just caused some confusion when Kirby started looking through the results.

Progress: All agreed upon deliverables have been received by the client, we were also able to complete some of the stretch goals purposed by our clients.

Plans: Moving forward, Nic and I plan on putting together a simple web application that will allow us to have additional information at expo. This might include, the plots we have on the poster but able to view at full screen, information about the side projects we worked on during the capstone project (ie. Ramdisk and tracing) as well as more general information about Oracle 12c and the features we experimented with. In doing so, we will be able to have a digital extension of our poster in hopes to provide a clearer picture to those interested.

#### **Nic:**

Problems: No significant problems for me other than I got a little busy during the week and was not able to devote much time towards the Expo web app.

Progress: On Monday we met to discuss how we should present our project at Expo and came up with ways to visualize our project by using Legos to demonstrate parallelism, table structure, etc. Aside from that, our project was more or less completed at this point.

Plans: Moving forward my primary goal is to work on the Expo web app.

### 1.5.6 Week Six

#### **Nathaniel:**

During this week, all of our efforts were directed towards preparing for expo. Our poster had already been submitted, but we still needed to prepare some pitches for people from varying technical background.

Problems: It was difficult to come up with a way to describe our project to a five year old or a grandmother.

Progress: We were able to get around this by creating an analogy comparing the database to a toy chest or a bank. We could focus on the organization aspects of a toy box for efficiency purposes, and focus on transaction latency in terms of the bank. Both of these examples can be used to demonstrate some of the need for our project.

Plans: Moving forward, Nic and I will be finalizing the expo app and further preparing the talk to people about our project by the end of next week.

#### **Nic:**

Progress: This week we primarily just focused on getting ready for expo, part of that was coming up with pitches for various audiences.

Problems: Coming up with pitches to describe our project to less technical audiences was challenging.

Plans: We needed to start finishing up the expo app that we would use as a poster extension.

### 1.5.7 Week Seven

#### **Nathaniel:**

This week we finished up the expo app and further prepared mentally for expo, it was important to come up with a loose script that we could follow when giving a brief overview of the project.

Problems: No problems were experienced during this period.

Progress: The app was finalized and we wrote up some pitch lines for multiple situations.

Plans: Friday is expo, the plan are to be ready and properly represent ourselves and the work that we have done.

**Nic:**

Progress: We finished up the expo app earlier in week by filling out the details of our experiments. Then Expo happened on Friday.

Problems: None.

Plans: None after expo.

### 1.5.8 Week Eight

**Nathaniel:**

Expo went great. It was somewhat laborious saying the same thing over and over again, but after the first couple of iterations we were able to get into a flow.

Problems: One thing that was unforeseen this week as that when we made the plots bigger on our poster, we accidentally covered up the bottom half of one of our sentences. This was not a big deal at all, but we did have someone comment about it.

Progress: We have completed all of our clients requested deliverables and made it through expo.

Plans: Before the end of the term we have three, or more, writing assignments. We will get more information later this week during one of our scheduled classes. Our efforts will be concentrated on finishing these promptly and completely.

**Questions:**

- If you were to redo the project from Fall term, what would you tell yourself?
  - I would probably tell myself to vote for James, our lost comrade, as the student I did not want to work with. The reason being that he did not contribute to our overall project, other than some documentation in fall, and it would have been better to have a full team. Nonetheless, Nic and I work really well together and we were able to take care of everything without another person. I would also tell myself to start a OneNote log of research at an earlier date. Our team could then rely on this for communal knowledge. This document could then be given to the clients for future reference.
- What's the biggest skill you've learned?
  - Proficient use of SQL. Based on the experience from the two database classes I have taken, I would say that I did not have the required knowledge to tackle some of the things we turned out during this project.
- What skills do you see yourself using in the future?
  - Definitely the skills I have gained in terms of SQL, but also the communication skills that were required to interact with our clients at a technical level is something that I am greatly appreciative of.
- What did you like about the project, and what did you not?
  - I really enjoyed the fact that I did not have a strong background in this field, this project was a growth period where I was able to broaden my scope of CS comfortability. Our clients were very supportive and made sure that we had everything we needed, they were also available after work hours. Initially, the project seemed like a big undertaking. The scope of what our clients wanted was quite broad, such as they did not know exactly what they wanted, this caused some initial stress early on. Also, the emphasis on documentation in the fall did not jive that well with what our clients were requesting.
- What did you learn from your teammate?
  - Nic was a wonderful student to work with. He is somewhat of a quite guy, but he brings a lot to the table. I think that the thing I learned most from Nic is trust in a group member. Early on it was quite dicey with communication between our group, this was mainly caused by James' lack of participation. It was great to have confidence in another teammate as someone who can stand on their own and produce equal if not better work. Without Nic on this project, I am not sure how things would have went.



- If you were the client for this project, would you be satisfied with the work done?
  - Absolutely, upon our first interactions with the client it was clear that they knew what there issue was but did not know how exactly to proceed. Nic and I were able to complete all agreed upon deliverables by the tail end of winter term, and then we started working on a completely different issue. Everything that was requested was done well before expo, if I were a client in a similar position I would be completely satisfied with our teams work.
- If your project were to be continued next year, what do you think needs to be working on?
  - Based on the last experiments we worked on, Indexing and Partitioning, there could be some work on correcting the naming convention issues in the test scripts. Additionally, emphasis could be placed on looking into bitmap indexes and bitmap joins, these implementations are said to be effective for data warehousing, however, we did not have time to set anything up to gather results.

**Nic:**

Progress Expo went well for us and we had finished our project objectives beforehand.

Problems No significant issues.

Plan Survive the rest of the term.

- If you were to redo the project from Fall term, what would you tell yourself?
  - When I first started the project I was taking notes with Google Docs during our client meetings. If I had to do it over again I would definitely use OneNote as far as notes and research goes. My notes on Google Docs weren't well organized and I had a separate document for eaching meeting which made going through all my notes a pain. Later on we switched to OneNote exclusively for our research and that worked out really well for us. Other than that I can't really think of anything that I could have told myself at the start to make the project easier because there were a lot of unknowns early on (e.g. what we would actually be researching, it was a learning process for all of us).
- What's the biggest skill you've learned?
  - When I first started this project, the idea of learning Oracle database seemed daunting since I didn't really know much about relational database management systems aside from basic setup and usage (setting up MySQL, basic queries). However, from just persistently researching and asking questions when needed for guidance we all learned a lot as we progressed through the project. More specifically, my mentors had taught me a lot about how Oracle database works (the architecture of it, how all the caches work, disk I/O, what actually happens when a query runs, different types of sorts/joins, etc.) but a lot of the concepts from Oracle database also apply to other RDMSs as well.
- What skills do you see yourself using in the future?
  - Before when I worked with databases in the context of an application I always treated databases as a black box that I send queries to and it returns data back to me. Now that I have a better understanding of the internal workings of a RDMS, I can use this knowledge going forward to use databases more effectively (how to diagnose slow performance, performance tuning, writing better queries, and so on).
- What did you like about the project, and what did you not?
  - I liked working with and exploring the internals of Oracle database/databases in general. The one downside of this is while Oracle database itself is pretty nice, the licensing is prohibitively expensive unless you're a company pulling in some decent revenue. So it was cool learning Oracle database but it sucks knowing you can't use it and it's cool features for personal projects unless you're willing to pay the average yearly salary several times over. I also feel that the documentation from Fall term did not really go with our project at all especially since we weren't even sure what we would be researching at the time.
- What did you learn from your teammates?
  - This group project was different from ones that I've been involved with in the past in that it was a year long and was a real project. Despite losing one member due to lack of participation, we were still able to pull through successfully and achieve the goals laid out by our clients. A large part of our success was Nathaniel being a proactive team member and a hard worker. We both learned from each other as we took on research topics individually and shared our findings. One thing I learned is if a team is short on members, you can still pull through if you trust your team and if everyone puts in effort.

- If you were the client for this project, would you be satisfied with the work done?
  - I would say so. We started off not knowing much at all about databases and were able to learn a lot about Oracle database throughout the project. Ultimately we were able to increase query performance by at least 4x, and increased overall system utilization (very little was being used before) compared to our baseline configuration.
- If your project were to be continued next year, what do you think needs to be worked on?
  - Some more topics that could be addressed are: bitmap indexing, attribute clustering, schema design, and other techniques that are related to increasing