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Customizing Web Applications for Beam Tomography

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Dear Sir:

This report, entitled "Customizing Web Application for Beam Tomography" was prepared as my 2B Work Report for the University of Waterloo. This report is in fulfillment of the course WKRPT 201. The purpose of this report is to look into the decisions that go into making a Web application from the ground up.

TRIUMF Canada's national laboratory for particle and nuclear physics and accelerator-based science, is one of the world's leading subatomic physics laboratories. The name TRIUMF was coined in 1968 from TRI-University Meson Facility. They are currently backed by 19 universities and doing research in more than just mesons.

This report was written for the Beam Physics Group at TRIUMF. They are involved with many aspects of the beam and its safe transportation through the beamlines. They work with different projects and experiments that require specialized beam delivery characteristics. They aim to do their work as efficiently as possible.

Other than input from select team members from the Beam Physics group at TRIUMF. I hereby confirm that I have received no further help other than what is mentioned above in writing this report. I also confirm this report has not been previously submitted for academic credit at this or any other academic institution.

Sincerely,

Samantha Kimberly Marcano
ID 20504667

Contributions

The team I worked directly with was relatively small it consisted of my supervisor, Thomas Planche, and a fellow co-worker, Carla Barquest. There were other members of a bigger group called the Beam Physics group that I interacted with who were Rick Baartman, Yi-Nong Rao, Evgeniy Tikhomolov and Suresh Saminathan. The entire group however, consisted of 9 people.

The team's goals were to look into the physics behind the transport of the beam through the beamlines and make it as efficient and safe as possible. They would work on many projects throughout the facility namely Cyclotron Projects, ISAC projects, ARIEL projects and Magnetic Measurements projects.

My task was to automate an existing work process from start to finish. This process involved taking readings from an active beam in the beamline using a wire scanner and through clever scientific calculations, reconstruct that beam in phase space so the emittance of the beam can be realized.

The relationship between this report and my job is a very close one. This report outlines the steps that I took in completing my tasks and some of the decisions that myself and my group faced along the way.

In the broader scheme of things, this is just one of the many processes that my group is looking into for automation. Physical research is still making groundbreaking discoveries and as technology advances, the use of faster, more efficient processes would aid the industry as it looks into the future.

Summary

The main purpose of the report is... . *or* The scope of the report is... .

The major points documented/covered in this report are... .

The major conclusions in this report are... .

The major recommendations in this report are... .

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1 Introduction

I was hired by TRIUMF as a Web Application Developer. I worked under the Beam Physics Group. My main task was to put together a Web Application that would take measurements from a physical wire scanner that is placed inside of the beamlines and provide a plot of the beam in phase space then calculate the emittance of the beam. This involved merging code packages that had already existed, i.e. written by physicists and writing new code snippets to fill in the necessary functionality for the entire application. The first steps, were to ensure that I was able to go from point A (raw data) to point B (reconstruction of the beam in phase space) conceptually. The work process during my 4 months at TRIUMF have been outlined in the following steps.

Firstly, I learnt how to use a Tomography package developed by physicist Yi Nong Rao. This will be considered a black box as I continue with my application. I would supply the Tomography package with sample input that was provided to me and observe the output and compare this output to existing output that has been previously achieved. I was then able to obtain new data that has not been prepared for input into the Tomography package. This is where I would begin the automation process for preparing the input. This involved cleaning up the raw data from the measurements for noise and splitting the set of data into its respective x and y components/profiles then smoothing the profiles using interpolation. Some of this work had been previously coded by Rick Baartman. I added additional processing to get the desired result. The data would then be formatted into a data file as input to the Tomography application. Then one of the outputs of the Tomography application is a matrix that can be used to make a contour plot of the beam that was reconstructed in phase space. At this point, I halted progress on continuing to process the data and began to take this application from a console application to a web application.

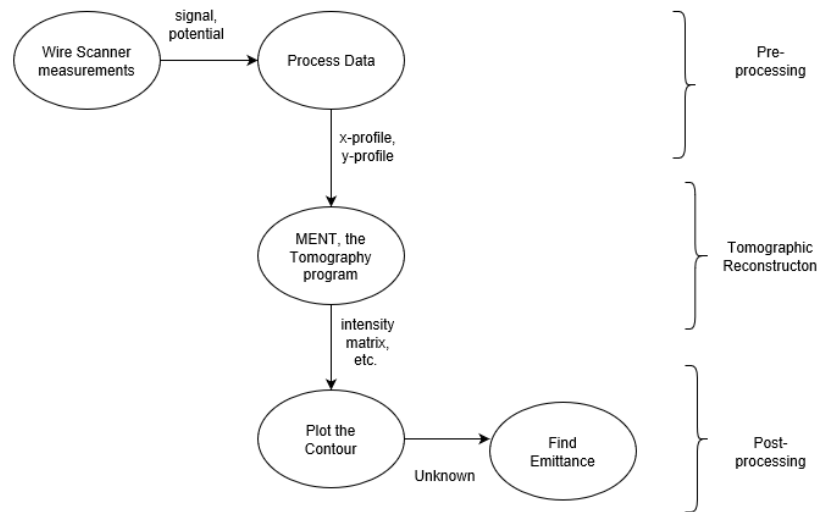


Figure 1-1. Diagram showing the flow of the application

2 Background

The beamlines at TRIUMF contain wire scanners Figure 2-1 that mechanically move into the path of the beam and measure its intensity. The wire scanners have two very thin wires that are at right angles to each other as seen in the photo. It returns this intensity and the position of the scanner's wires as it takes readings. A typical plot would show the intensity rising and falling as signal (intensity) vs position Figure 2-2.

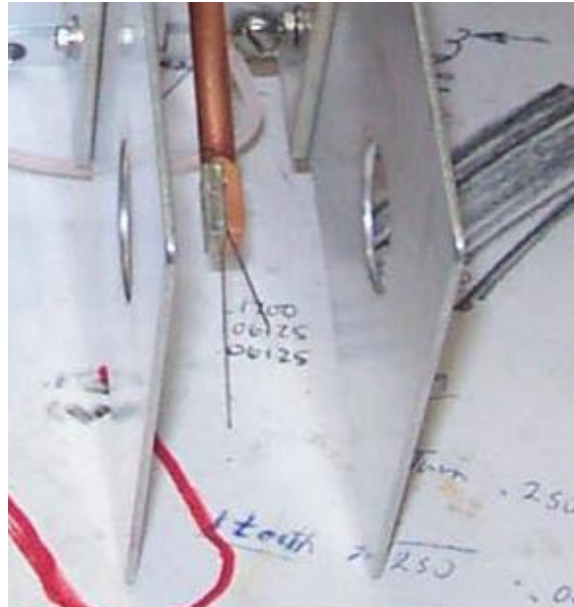


Figure 2-1. Sample wire scanner inside the beamline, a close up of the wires

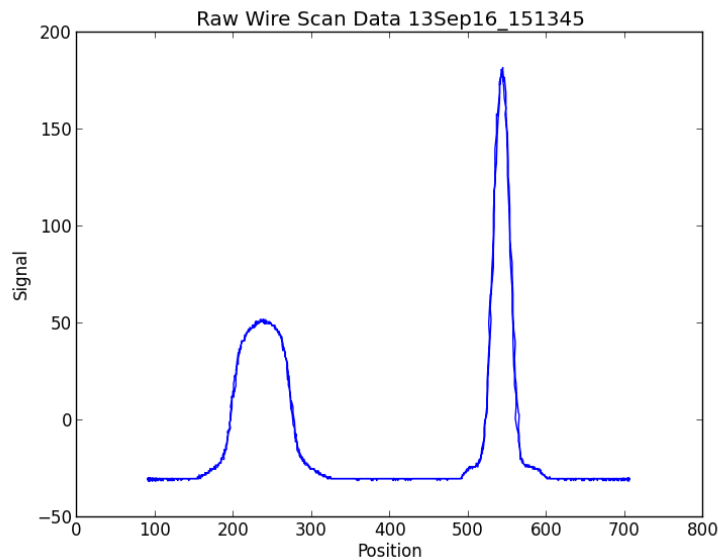


Figure 2-2. A plot of signal vs position given by the wire scanner

This describes the path that the wire scanner takes into and out of the beam to return to its starting position. These readings give physicists information about the beam inside of the beamlines because it is not always constant. Factors influence the beam and the right tune needs to be defined in order to get the beam safely through the beamline and arrive with the characteristics needed by experiments. Thus, the developed application will be used to process many of these results in real time and provide a tomographic reconstruction of the beam Figure 2-3. The application will also aim to access past data so historical beam reconstruction can also easily be achieved.

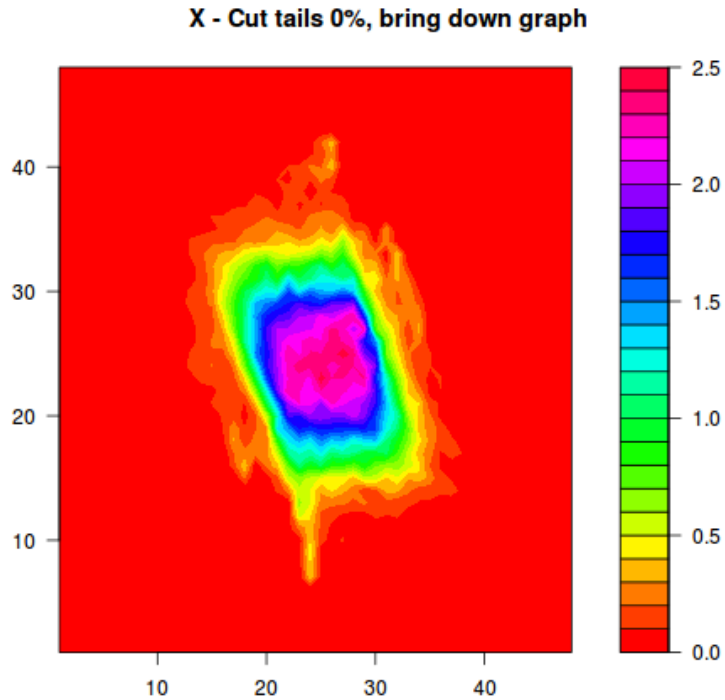


Figure 2-3. Tomographic reconstruction of the beam

3 The Engineering Problem

The Engineering Problem is that The Beam Physics Group at TRIUMF would like to analyse the beam in a certain way using wire scanner data. They currently do not have an efficient means of analyzing this data. Each physicist would use their own code that is written in different languages to get from the raw data file to a meaningful processed output. Some of the process would even be manually done. This was not feasible as many physicists would like to make use of this analysis process and occasionally updates would have to be made to the this application so the source code would have to be continually distributed. As a co-op student, I have been hired to solve this problem for them. My task is to write a web application that automates this process.

There are many decisions that go into writing a web application. These aspects collectively may go under the umbrella of functional specification discovery. According to Comentum 360, functional specification discovery involves "brainstorming, learning and making decisions on the feature details, functionalities, user interaction flows, priority and flow of navigational system, interface elements and content, usability and required user experience items as they relate to the project, etc.." This project will be mostly concerned with client side scripting, server side scripting and Data Storage and Structure.

4 Requirements, Criteria, and Metrics

The requirements of the project as per discussions with a physicist. The use of open source technologies is preferred due to issues with licensing inside of the company. The application needs to be available to more than one user. Not necessarily more than one user at a time but there will be many different users so ideally a web application. The user interface should be simple and not cluttered. The application should perform calculations efficiently and correctly. The solution should be fast and be able to run in real time. Also, there must be a working solution in a four month period so the level of complexity cannot be too high. From these requirements, the criteria that will be used for analysis are as follows.

1. Time - The amount of time that would be needed to complete the project
2. Complexity - I am a co-op student, I'll run into problems and I need resources to help fix these problems
3. Does it solve the problem - Can tomography now be run from start to finish with just the click of a button
4. Ease of use - Can they use the program easily
5. Easy of maintainability - who will maintain and will it be easy for them to maintain?
6. Mathematical Capability - Ability of the solution to perform complex calculations in real-time

5 Possible Solutions

In order to solve this problem, there are many parts to the solution. The overarching one is that it has to be a web application so no other options were considered there. Now, I have had some experience with C# writing a web application in ASP.NET using Visual Studio but in the interest of not being tied to licensing obligations, open source programs are preferred by the group. Thus, I looked at a server-hosted python template application for guidance. This program was written for the Beam Dynamics group by a previous co-op student. Python was also suggested by the IT personnel at TRIUMF due to its versatility and popularity in industry nowadays. Some of the code

snippets that I had received were in Fortran. Hence, that would also become an option to help reduce coding time. I have also worked with SQL Databases and were leaning towards those for use as data storage but past applications within the group have used XML files for data storage. Also, past applications have been done using JQuery and CSS but a new employee in my group had been researching and implementing Bootstrap as a CSS framework instead of writing all of their own CSS for an existing website so this was also an option.

In order to bring the entire project together, all of the main aspects of a web application need to be addressed. Namely, data storage, functionality language and user interface. Thus, data storage we will be considering database or XML files. Functionality scripting would look into Fortran or C# or Python. GUI options include Bootstrap or CSS.

As a preliminary step we would combine these different technologies in different ways to get a complete solution then looking into the pros and cons of each of the tools against each within the same category and then how technologies in different categories complement each other. The following table shows several combinations of solutions that were considered at the beginning of the project.

Table 5-1. A table of Possible Solutions

	Data Storage	Functionality Language	UI Scripting
Solution 1	SQL Database	Fortran	Bootstrap
Solution 2	SQL Database	Python	Bootstrap
Solution 3	XML	Python	Bootstrap
Solution 4	XML	Python	CSS

6 Engineering Analysis

In order to most effectively combine the best set of technologies for the job at hand we will first compare the options under the same category then explore how the combinations of each will affect the overall solution.

6.1 XML vs SQL Database

The data that needs to be stored is the results of the scan that was done on the beam. This consists of anywhere between 2500 and 3000 pairs of data points that represent the signal at different positions of the beam as the wire scanner itself took measurements. It would also store a few settings of the mechanics of the beamline for reference along with date and time stamps. This is considered the raw data. This must be stored for each scan. However, if a user is interested in particular scans as evident by selecting them to view more information, then more processed data on the scan is

written to storage. If a user is never interested in the scan data then only the minimal amount of data is stored. We will take a look at the data that needs to be stored in order to justify this conclusion. For a full account of the data please refer to Appendix B.

A sample of the raw data:

```
<scandata dateStamp="13Sep16" fileName="WS063_13Sep16_151527.dat"
  locationID="WS063" timeStamp="151527">
  <cs_r numpts="2569">
  <!-- Control System Data (cs - control system, r - raw) -->
  <position>
    92 92 92 92 92 92 ... 92 92 92 91 92 91 92 92 92 92 92 90
  </position>
  <signal>
    -30 -30 -30 -30 -30 -31 -30 ... -30 -30 -30 -30 -30 -30 -30
  </signal>
  <comment/>
</cs_r>
```

This should be kept in mind as we examine the pros and cons of XML and SQL Database for this purpose.

It should be clear that XML files are not considered a database. XML is being considered is because the use of XML for storage has previously been used within the group due to the low level of relations within the data that needs to be stored. XML is simple and easily maintainable. XML files are simply text files stored on the computer and only the program that was written can access it. Reading and parsing a file is also slow and modifying it is even worse. Relational databases have been proven tried and true. On the other hand, there are database applications that were built for storage applications, they can run on a different server to facilitate load sharing. Physics calculations can get intensive so this could be a good set-up if processing requirements hinder performance. XML uses more or less sequential access methods whereas SQL databases have indexes so it is more direct. It has been outlined that small hierarchies are good in XML and SQL databases are not generally needed and if the data does not fit naturally into a database then XML could be better.

Given this information, XML seems to be better for this particular situation. The data is not relational and it is more or less constant.

6.2 Fortran vs Python

There are two kinds of languages. Those that minimize the time programmers spend programming, Python, and those that minimize the time computers spend computing, Fortran. As computers become faster and human resources become more expensive, we are tending towards the latter. Fortran has support for mathematical calculations and is used by many physicists. Its performance is very high and it sees scientific programming as its target audience. It gets the job done efficiently and someone who has used it as a main programming language for many years I can see why some physicists are reluctant to change. However, Python is becoming more and more popular. It combines power with clean, simple syntax. It is a good language for doing mathematical computing. Both Python and Fortran are open source.

When it comes to extending these languages for use within a web application, Python seems like the better way to go due to its growing recognition in industry and it matches the capabilities of Fortran.

6.3 Bootstrap vs CSS

The development of the user graphical interface is known as client side scripting. This is what the end user interacts with in order to observe the capabilities of an application. During this project, it has been clear that this is what the user cares about most. Not just the way the GUI looks but how the functionality behind the GUI can be brought forward at the click of a button. Traditionally a key aspect of web design was HTML, CSS and Javascript. In the interest of making things run smoother frameworks were developed. Some advantages of frameworks include:

- Prevent repetition between projects
- Utilize responsive design to allow your website to adapt to various screen sizes mobile, desktop, and everything in between
- Add consistency to design and code between projects and between developers
- Quickly and easily prototype new designs
- Ensure cross-browser compatibility

According to W3schools "Bootstrap is the most popular HTML, CSS and Javascript framework for developing responsive, mobile-first web sites." It clearly surpasses writing your own HTML, CSS and Javascript pages but since this application was being developed along with other similar applications that has already been completed, there was existing framework that could be re-used.

6.4 Decision Matrix

A decision matrix will be used to evaluate the feasibility of each of the solutions outlined in the previous section. Thus, the weights have been given based on how strongly each item stands as a requirement, criteria or metric.

Table 6-1. Decision matrix for possible solutions

	Solution 1	Solution 2	Solution 3	Solution 4	Criteria Weight
Time					10
Complexity					20
Maintainability					20
Performance					10
Scientific Capabilities					15
Solves the Problem					25
Total					100

Conclusions

From the analysis in the report body, a conclusion would be drawn for the best solution, it may or may not be the solution that was implemented (XML, Python, CSS). However, both will be justified.

Recommendations

Based on the analysis and conclusions in this report, recommendations regarding the project would include moving to the ideal solution if it was not the one that was previously implemented. Also, continuing from the point of the contour plot onto the emittance scans. Also, the idea that this will be used for more than one beamline so some more abstraction than already exists would need to be done.

References

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<lin12.triumf.ca/text/2009PAC/YNRAO/1/TH6REP041.ps>

<http://www.comentum.com/guide-to-web-application-development.html>

<http://www.w3schools.com/bootstrap/default.asp>

<https://www.taniarascia.com/what-is-bootstrap-and-how-do-i-use-it/>

Appendix A Title of First Appendix

Use the No Spacing style.

Appendix B Sample XML Layout

```
<scandata dateStamp="13Sep16" fileName="WS063\_13Sep16\_152345.dat"
  locationID="WS063" timeStamp="152345">
  <cs\_r numpts="2999">
  <!-- Control System Data (cs - control system, r - raw) -->
  <position>

  </position>
  <signal>

  </signal>
  <comment/>
  </cs\_r>
  <pm\_r c14="-0.0115" c23="-0.0526" t14="0.0957" t23="0.2051">
  <!--Minimally processed data. (pm - profile monitor, r - raw)-->
  <profile\_1 center="-0.0126" twoRMS="0.0954">
  <position>

  </position>
  <signal>

  </signal>
  </profile\_1>
  <profile\_2 center="-0.0546" twoRMS="0.2053">
  <position>

  </position>
  <signal>

  </signal>
  </profile\_2>
  <profile\_3 center="-0.0506" twoRMS="0.205">
  <position>

  </position>
  <signal>

  </signal>
  </profile\_3>
  <profile\_4 center="-0.008" twoRMS="0.0966">
  <position>

  </position>
  <signal>

  </signal>
  </profile\_4>
```

```
<comment/>
</pm\_r>
<pp\_1>
<profile\_x>
<position>

</position>
<signal>

</signal>
</profile\_x>
<profile\_y>
<position>

</position>
<signal>

</signal>
</profile\_y>
<comment/>
</pp\_1>
<pp\_2>
<profile\_x>
<position>

</position>
<signal>

</signal>
</profile\_x>
<profile\_y>
<position>

</position>
<signal>

</signal>
</profile\_y>
<comment/>
</pp\_2>
</scandata>
```