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Creating Business Analytics Dashboard Designs using Visualization Methodologies: Case Methods for Innovative Analytics Pedagogy

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Abstract

Teaching business analytics has become a critical requirement in many business schools to stay competitive, and the search for real-world examples of business analytics applications is a subject of great interest among analytics instructors. Instructors want to be able to show students how to develop and build business analytics applications that can effectively help real world business decisions. In this research, we aim to develop teaching methodologies to design visual analytics applications that are effective at the classroom and at the same time practical for students to relate to when building their own dashboard application. This research attempts to showcase these designs in case studies where analytics applications are create to help students understand how they are used in various business operations.

Keywords: Business Analytics, Application Design, Dashboard Design, Design Methodologies

1. INTRODUCTION

The sheer amount of data and analysis needed in today's business environment needs to be addressed by visual interfaces that are intuitive to use and easy to comprehend (Keim, Kohlhammer, Ellis, & Mansmann, 2010). The overwhelming amount of textual and numeric data is difficult to decipher without the help of visual analytics.   Dashboard design is an important tool in creating effective analytics applications. According to Jerath, Crawford, & Barnes (2015), over fifty percent of the human brain is dedicated to vision and visual representation.

The purpose of this paper is to share various dashboard design methodologies used in a business analytics class, which has been effectively used by students to create their own customized dashboard projects.

In order to understand the details of creating an effective visual representation such as a dashboard application, we need to understand how the human mind perceives visual information. Essentially, human perception responds to – color, shape, motion, and depth of objects seen by the human eyes (Mueller, 2010).

Accentuating certain visual patterns can quickly alert human perception of certain information and effectively help human cognition in digesting data more effectively and in turn, help people make more informed decisions. Thomas (2007) stated that visual analytics can provide solutions and opportunities to resolve information overload. Colors and unique shapes of objects can alert human perception to critical and dynamic visual information, especially when the information is represented in unique object shapes and color codes. Motion like animated charts and real-time adjusting numeric representations also improves human perception of data. Depth, represents three-dimensional representation, which may be better than just flat two-dimensional representation. Visual

design layout of dashboards are also critical for improving perception, since layout can give clarity to navigate through information clutter.

2. LITERATURE REVIEW AND DESIGN METHODOLOGIES

Looking at the dashboard design literature, there are several recommendations for designing a good dashboard application. Hertz (2019) summarizes the best dashboard design practices in a few words "Make the complex simple; tell a story; the data visualization needs to correctly reflect the data; and reveal details as needed (no more no less)." Durcevic (2019) has several design recommendations including "choosing your end goals before putting the design elements in place; choose your layout and colors; prioritize simplicity; and use interactive elements" to name a few. Smith (2012) talks about using multiple data representations, such as using secondary statistics in a dashboard display to support a metric and give it better context. For example, instead of just stating that sales has increased by 25,000, a dashboard can also show that it grew by 25% from last month. The 25% percentage growth is the "secondary statistics" that give the raw sales data a better context. Smith also recommends displaying small charts alongside numeric data to improve visualization.

In this research, we look at several techniques to improve the design of business analytics applications. The following are some methodologies we used:

1) Redundant Visual Representations - When viewing a dashboard application, a digital representation may not be enough. We may also need an analog representation at the same time to enhance visual data perception. Watchmakers have used this dual analog-digital presentation when designing watches, where you have a numeric digital representation of time and also have the three hands of an analog clock showing the hour, minute, and seconds of the time in the layout of the watch. Woodford (2019) explains that both analog and digital displays have their own merits in conveying information that appeals to various users. When designing visual applications and depicting data output as a gauge, it helps when you have dials to show where the numeric value is in an analog form in addition to showing a numeric value. (See **Figure 1** in Appendix).

2) Clear Layout for Input and Output Objects – In any information systems, there are generally three major processes – (1) inputting data into the system, (2) processing that data into useful information, and (3) and generating an output to show meaningful knowledge that can be extracted from that data. Determining what inputs are important will ultimately show how effective the output is in helping the user of that system. In a dashboard application, there are visual objects that you can use as your data input. These data input objects are used to adjust any data input for purposes of data manipulation and data simulation. On the other hand, there are also visual objects that you can use as your visual data output or data results. For example, in a car, a 'gauge' is a visual data output. A speedometer gauge shows the results of your speed as you step on the gas pedal. The speedometer gauge is the visual data output that helps you monitor how fast you are driving, while the gas pedal is your input mechanism. However, in this example, the gas pedal is not a visual input but a mechanical input. In a dashboard application, you can use visual dials or sliders to adjust your data input (See **Figure 2**).

3) Using Colors for Indicators – the human eye can easily spot certain color indicators more easily and there are ways to make certain data patterns stand out. According to Dashburst (2018), "Color has been known to have a powerful psychological impact on people's behavior and decisions. And this knowledge has been harnessed all too well in marketing psychology by designers and marketers alike. Color can often be the sole reason someone purchases a product. In a survey, 93 percent of buyers said they focus on visual appearance, and close to 85 percent claim color is a primary reason when they make a purchase." Color coding is part of the visual strategy for using colors effectively.

4) Story Telling and Creating Visual synergy – Creating an Analytics application needs some story telling. What do you want to convey to your audience. How does your application interest the user and how will the data tell the story. An application will need the right elements to attract audience to use them. For example, if you are developing a predictive analytics application to forecast a future scenario, the user will assess whether you have taken into consideration the most important data that can affect the accuracy of future scenarios. The user will also assess whether the mathematical and statistical model is logically and theoretically sound.

5) Defining the Scope of your Application and Range of Data – Analytics applications are meant to be compact and effective. A dashboard designer cannot put too many variables into it or it will be too cumbersome or complex to use, unless it is customized to for one specific user or a very few specialized users. The idea of analytics dashboard is to keep it as simple and as user-friendly as possible, and not to encumber data analysts with extra variables that have minimal impact on the outcome. So, the Dashboard application will have its own limitations in terms of scope. The data variables may also have a limited range, because in the real world you try to measure or benchmark certain data in a certain range of values. For example, when designing the speedometer of a car, the range is normally from 0 – 180 or 200 miles per hour. It does not make sense to create a range to include 1,000 miles per hour, because no car on the road will exceed that kind of speed.

3. CASE 1: MORTGAGE ANALYTICS

The first case aims to teach students how to create a mortgage analytics application. All banks and mortgage lending institutions use some form of mortgage analysis to help their clients decide on questions like (1) how much they should borrow on a housing mortgage, (2) can they afford such a mortgage, (3) if they have an existing mortgage, will they save money if they refinance their existing mortgage?

There are several factors that determine the monthly amortization or payment of a mortgage. And these are (1) the loan amount being borrowed, (2) the term of the loan (whether it is a 30 year, a 15 year, or a 10 year mortgage, (3) the interest rate of the mortgage (shorter term mortgages tend to have lower interest rates), and (4) the escrow amount, which is an amount the bank collects on a monthly basis to pay for the yearly realty tax on the property and the home owners insurance. So, to create a mortgage application, it is safe to assume that these four factors (loan amount, term of the loan, interest rate, and escrow amount) are the basic adjustable data inputs that determine the outcome or output. The output is to find out what the monthly amortization or payment is. The data output report can be two-fold, one showing the monthly amortization without the escrow payment and the other showing the monthly amortization payment with the escrow amount being paid. The reason that it is important to show two outputs is that the monthly amortization for a fixed 30 year mortgage payment will not change for 30 years, but due to the rising cost of home insurance and potential changes in real estate taxes, the escrow amount could change from year to year.

If the bank's client has an existing mortgage, we can add one additional data input and that is the current mortgage amount the client is paying. We can also add one additional data output and that is, how much will the client save if the client refinances to a new mortgage. It is a logical expectation that many home owners who are interested in refinancing their mortgage wants to lower their monthly mortgage payments, and possibly save a few hundred dollars in monthly mortgage payments.

In **Figure 3**, we built an analytics dashboard application for mortgage analysis using SAP Business Objects Dashboard. We decided to create a layout where most of the data "input variables" are on the left side and the "output variables" are on the right side of the application template. On the left side, the input variables include the Loan Amount, Interest Rate, and Escrow Amount. On the right side, the output variables include Monthly Amortization with No Escrow and Monthly Amortization with Escrow. SAP Business Objects can import Excel formulaic functions like the =PMT formula that calculates mortgage payments based on loan amount, interest rate, and the term of a loan.

In the middle, a dropdown menu was created allow users to choose a loan term of 30, 20, 15, 10 and 5 years. If a client has an existing mortgage and wants to refinance that mortgage, that data can be inputted there, and an output

data shows the savings realized from the refinancing effort is also indicated. In Figure 3, we can see a client has an existing mortgage payment of $1,350 and that client is getting a new mortgage payment of $993.57. The difference between the two amount results in a savings of $359.43 per month.

In **Figure 3**, the application also uses a redundant method of using both 'horizontal progress bars' and 'dials' allowing users to use any of the two data input objects to adjust the loan amount, the interest rate, the escrow amount, as they please. Using redundant representations makes it easy for users to use adjustable visual input objects as they see fit.

4. CASE 2: SALES ANALYTICS (USING AN INTERACTIVE DATA MAP)

For the second teaching case, we use a fictitious small company selling 6 different products across 50 states. The input object is an interactive map (see **Figure 4**). If the user hovers the mouse pointer above the location of a particular state on the map, it will pop up the total sales number of that particular State on the map. And it will create a real-time output of the sales breakdown in a pie-chart and a table for each product in each of the 50 U.S. States. A second pie-chart also shows the percentage of sales that a particular state contributes in relation to the total sales of the company. The data on the map is linked to the pie charts and the tables. When a State is choose in the map, the pie chart and table data automatically shifts to that particular state's data.

The map is color coded to depict different sales levels. The green colored states reflect sales that are below $10,000. The purple colored states are those that have sales between $10,000 - $15,000. The yellow colored states are those that have sales between $15,000- $20,000. And the Red colored states are those with sales above $20,000. The application allows users to determine what color to use.

5. CASE 3: PREDICTIVE RETIREMENT ANALYTICS

For those who are planning for retirement, it is always difficult to determine if their nest egg or life savings can last thirty or forty years. There are several critical factors that affect the longevity of one's retirement savings. Most individuals contemplating retirement can benefit even from a simple predictive analytics model that can help them estimate how long their retirement funds can last. In a very simple

predictive analytics model (see **Figure 5**), there are at least five input data variables that can determine how long one's retirement nest egg can last. (1) The starting balance of one's nest egg upon retirement, (2) the age of the retiree, (3) the average yearly growth of one's investment portfolio base on the historic performance of the stock market in the last few decades (measured by the Down Jones Industrial Average and the S&P 500), (4) how much one withdraws from their retirement savings every year as their retirement income (based on their yearly budget for yearly living expenses), and (5) the projected inflation rate, which erodes the value of money year over year. So the yearly withdrawals from savings will increase base on the yearly inflation. If a person can live or survive on a budget of $48,000 per year at the start of their retirement and they have social security income at $12,000 per year, then they will need to withdraw $36,000 from their retirement savings to supplement their social security income. On the second year of their retirement, they will need to adjust the $36,000 spending budget due to inflation. If inflation is 2%, that means they will need to withdraw $720 more on the following year ($36,000 x 2% = $720). This assumes that social security is also inflation adjusted.

The retirement analytics application allows users to adjust the input variables located on the left hand side of the application, and it should determine if the retiree still has some savings left at the end of a 30 year or 40 year retirement period. The right side of the application shows gauges that determine the savings left after 30 years and 40 years of retirement.

6. CASE 4: INDIVIDUAL CUSTOMIZATION OF RETIREMENT ANALYTICS

In Case 3, we developed a dashboard analytics application that can be quickly used by anyone to create a more generic predictive analytics for retirement. However, we created another predictive retirement dashboard application for Case 4 (see **Figure 6**) that is individually customized for a person who had plan to retire at 53 years old and was about to reach that age in a few months. Since the person was only 53 years old, he had 6.5 more years to be able to withdraw from his 401K and IRA account at 59.5 years old without incurring a 10% tax penalty, so he has to rely on his cash savings and determine if his cash savings will be depleted soon. The person also planned to withdraw

social security income with his spouse at the age of 62 years old, so we customized a dashboard application just to see the balance of his cash at 62 years old, and the potential income he could receive at 62 years old as he and his spouse plans to take their social security at that age.

The person also took into consideration that there is an Internal Revenue Service (IRS) loophole called Substantial Equal Periodic Payment (SEPP) that would allow him to withdraw from his retirement account before reaching the age of 59.5 years old without the 10% tax penalty. SEPP (Appleby, 2019) allows people to withdraw an equal amount of funds for 5 years or more, but the withdrawal must be an "equal amount". It means that if a person decides to start withdrawing $12,000 a year from their 401K, then they must withdraw $12,000 a year for the next 5 years and they cannot change that amount to follow the SEPP IRS rules. So, this is an option if an early retiree feels that they will run out of cash before they reach 59.5 years old or 62 years old when social security is available. This individual also plans to do part-time work in different age periods of retirement, but plans to earn less as he approaches the age of 62-63 years old. So, we included four adjustable income gauges for different age periods in the dashboard application. At 62 years old, the person also plans to put most cash into Municipal Bonds earning 6%. So the customized dashboard has a multiple income source tally at age 62, from his social security income, his wife's social security income, his 401K withdrawal at 4% per year, and municipal bond income at 6% (**Figure 6**).

7. SUMMARY

In these four dashboard application design cases, we used the design methodologies we discussed earlier in the paper. We used redundant visual representations to display both analog and digital representations for the data we want to convey to the user effectively. In the mortgage analytics applications, for example, we used a gauge with analog dials and a digital display of numeric values. In the design methodologies, we discussed how colors and color coding is important in dashboard design. We used color coding to represent different data representations like the interactive map with colors representing different numeric sales value. We also used color codes for data inputs, like horizontal bars, and output objects, like gauges. For the retirement analytics, a negative balance results in the gauge range as red, and green if it is a positive number.

In terms of the layout for the mortgage analytics and the retirement analytics, we placed the input variables on the left side of the template, and the output variables on the right side of the template. The interactive sales map, which acts as an input object, for the user to choose a specific state is also on the left side of the template, and the right side of the template shows the breakdown of the sales data based on the state chosen on the map.

For the individually customized dashboard analytics for retirement, most of the inputs are on the left side and the output gauges are on the middle and the output chart is on the right side.

As indicated in the design methodology, each of these application tell a story about how various input variables are related and affect the output variables when the input data is adjusted by the user. The input data variables can be adjusted on the fly and create various output scenarios in real time based on how the user of the application configures the input data variables. Once the users visually adjust the input variables, they immediately see the real-time adjustments on the output variables.

In all the dashboard applications, we followed the design methodology to stay within the scope of the application envisioned in terms of including all the inputs and outputs we wanted to present, telling the right story, designing an intuitive layout and using colors appropriately to improve cognition. We also designed a realistic range of data, like setting a more realistic range for inflation rates and interest rates.

In the classes where we taught these design cases, students were required to create the mathematical model in Excel first where they see how input variables affect output variables. Then, we imported the mathematical model in Excel to the SAP Dashboard application and then designed the Dashboard objects (like gauges, data bars, charts) around the Excel mathematical model. The SAP Business Objects allow you to link these Dashboard objects to specific Excel-like cells. Students are asked to design about 5 to 6 of these dashboard cases. After they have a feel of how to model and represent data in a dashboard application, they are then required to collect data they want to analyze and design their own dashboard projects. They are graded based on (1) purpose of their dashboard application, (2) the data they collect, (3) the mathematical model they create, and (4) the layout, colors, and design details of the dashboard, and (5) the overall synergy of

their dashboard application and its parts and how it appeals to the user.

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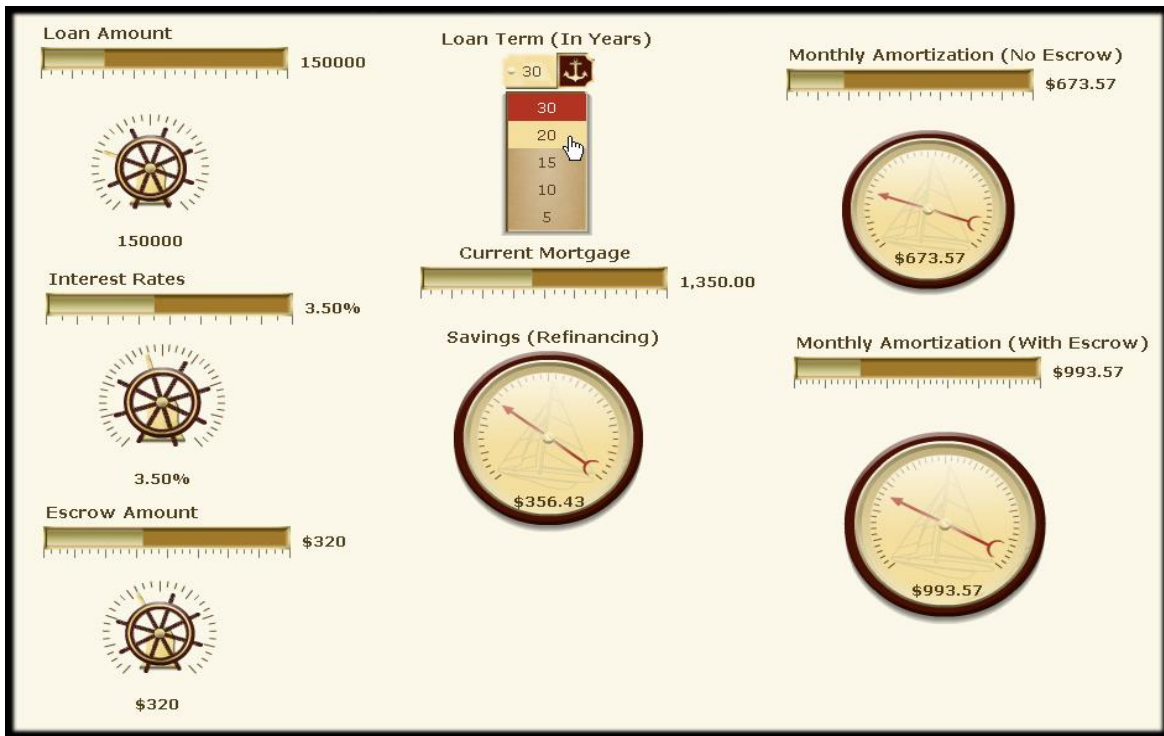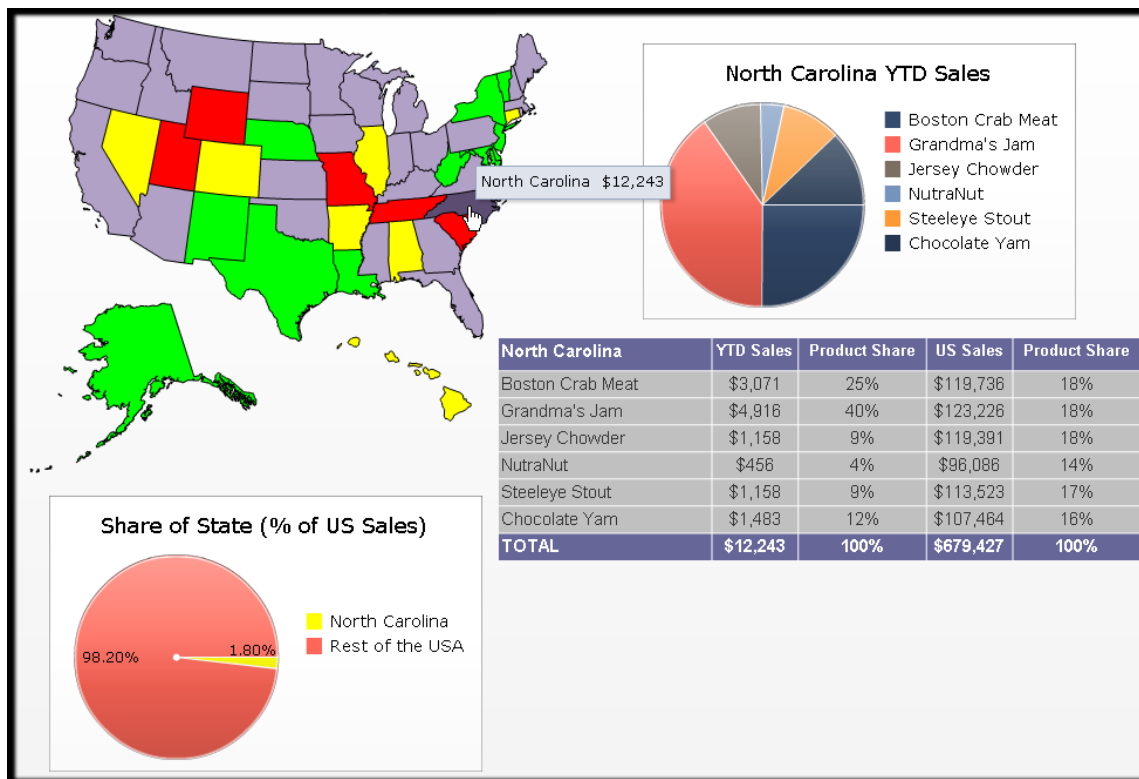
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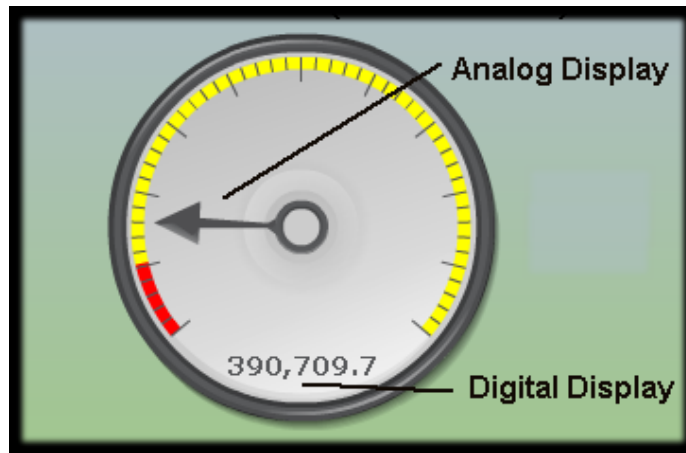
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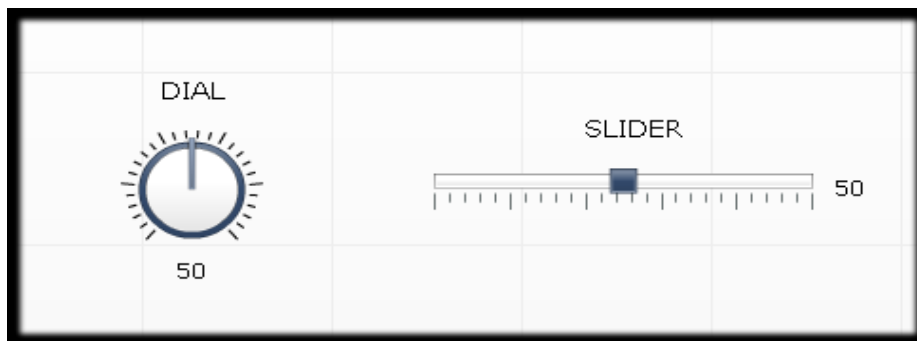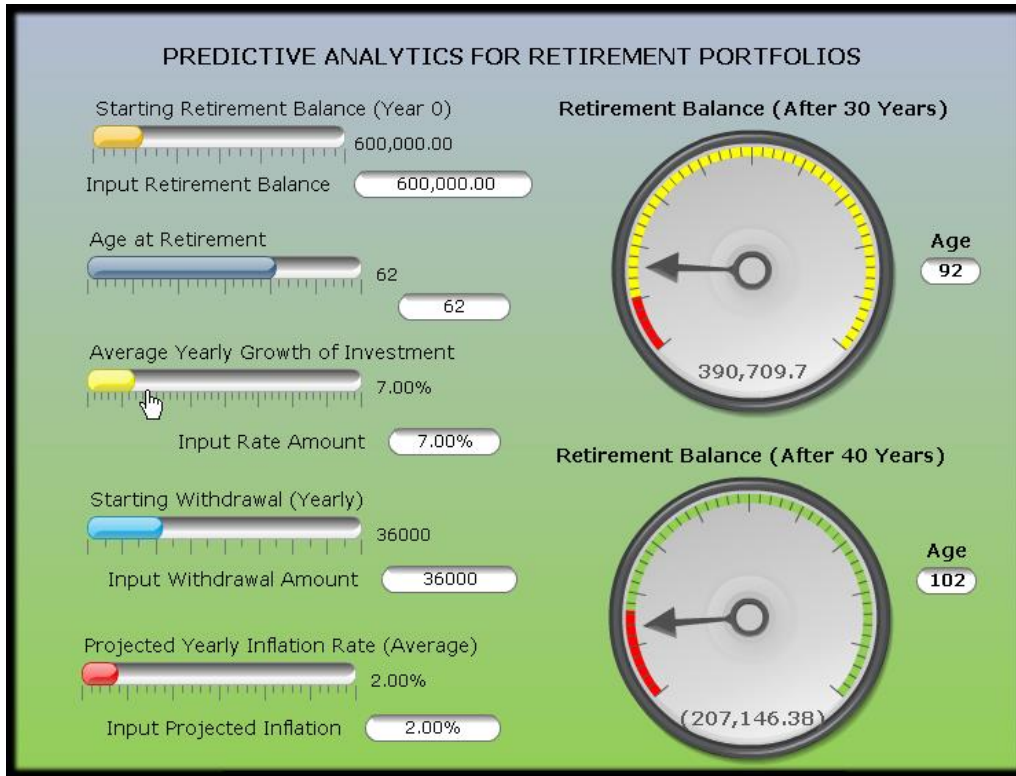

Figure 2.   Dials and Sliders as objects used to visually adjust data Input with a mouse pointer
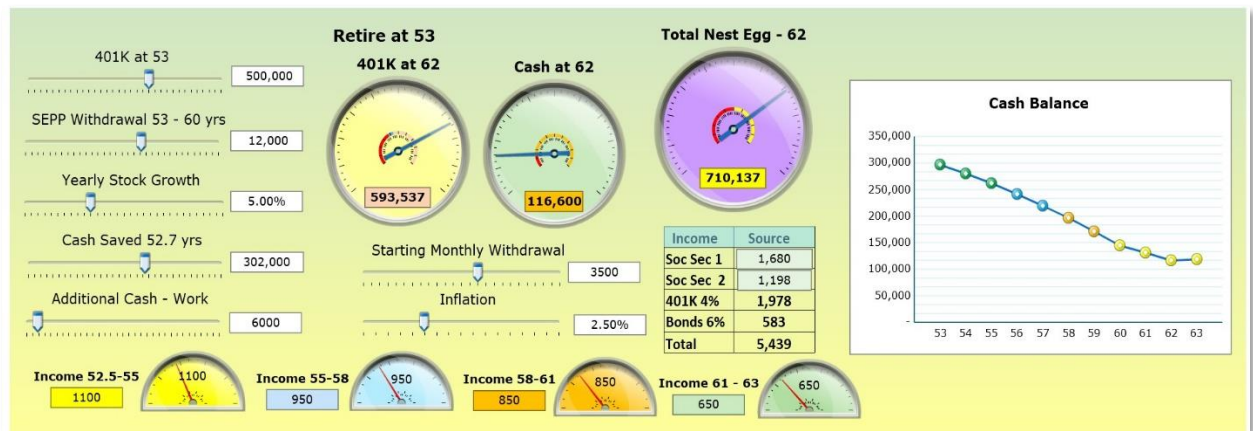
Figure 3. Mortgage analytics with most input objects on the left side and output objects on the right side

Figure 4. Interactive Map of the Sales numbers for each state.

Figure 5. Creating a forecast for retirement

Figure 6. Customization for Individual Retirement Analytics

*All figures are originally created by the author(s)