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A Visualization Scheme with a Calendar Heat Map for Abnormal Pattern Analysis in the Manufacturing Process

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ABSTRACT

Abnormal data in the manufacturing process makes it difficult to find useful information that can be applied in data management for the manufacturing industry. It causes various problems in the daily process of production. An issue from the abnormal data can be handled by our method that uses big data and visualization. Visualization is a new technology that transforms data representation into a two-dimensional representation. Nowadays, many newly developed technologies provide data analysis, algorithm, optimization, and high efficiency, and they meet user requirements. We propose combined production of the data visualization approach that uses integrative visualization of sources of abnormal pattern analysis results. The perceived idea of the proposed approach can solve the problem as it also works for big data. It can also improve the performance and understanding by using visualization and solving issues that occur in the manufacturing process with a calendar heat map.

Key words*: Data Visualization, Abnormal Pattern Analysis, Manufacturing, Calendar Heat Map.*

1. INTRODUCTION

Recently, most of the industries around the world use data to record work and business process. Before technology developed rapidly, hand-written paper documents were the main source of recording, which had a high risk of security, and low efficiency of keeping a large quantity of data. There have been numerous innovative ideas to overcome this limitation. Many researchers focused on algorithms that deal with big data. Big data became the state-of-the-art framework for massive storage amount of data and intelligence; it can be used both in scientific research, education, and other different sectors around the world. In addition, big data [1] can be improved to high performance with the application of various algorithms. In this paper, we demonstrate the new technology that can efficiently handle big data, enable users to understand it easity, and have more flexibility in controlling the data.

A famous search engine, Google, tracks the user's search activities and stores these activity data in database. Therefore, Google's storage capacity has increased dramatically over the last years. In banks, the credit card usage data is stored in the database. In above situations, we store the data in database because it can be later analyzed and provide the useful knowledge. However, a massive amount of data is not easy to manage as it takes a huge amount of time to extract even a single record. Thus, there is a need for the data analyzing techniques that can deal with such huge amount of data.

Raw data has not been analyzed well yet. Thus, we regard the data as abnormal data. It is most necessary to train the data to become high-efficiency data. We have many techniques to control the huge amount of data and analyze of abnormal data. However, these techniques are not completely adapted in manufacturing industries. In fact, the manufacturing industries [2], [3] face a continuous strain due to the increasing input costs and sharply increasing expectancies of the consumer.

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Additionally, brief manufacturing time and high quality are the critical elements to be fulfilled. For that reason, efficient and consistent optimization of manufacturing strategies is essential to perform efficiently on the market.

Because of the rapid development of PC hardware and sensor technologies, manufacturing [4], [5] industries have gathered a big amount of data that often come from the producing process, while delivering chain management and other legacy systems. As soon as the analysis is done and the useful knowledge is identified, we can pass these data to the experts for the optimization of production strategy. However, due to the massive quantity of facts, acquiring the useful knowledge hidden in the data can be a hard task.

Information visualization is able to facilitate the evaluation of the data in manufacturing industries. Mainly, it may offer a graphical illustration of diverse tasks, along with tracking the manufacturing process [6], monitoring the production environment, coming across tendencies and patterns, and a better understanding of ordinary manufacturing process. In this paper, we focus on data visualization [7], which provides various information details to users with high efficiency. Specifically, we focus on manufacturing data that is a necessary to be analyzed. The analyzed data affects the manufacturing industries to optimize their product with high quality. For these reasons, we propose the idea of abnormal pattern analysis visualization using calendar heat map.

Nowadays, high quality of goods is crucial, which can also be affected by the delivery of the product and standard organization. On the other hand, it also urges the developer to try more efforts to develop their service to a higher level than before. In these cases, data outlier can cause many problems in the manufacturing process. In this paper, we propose a visualization scheme with calendar heat map for abnormal pattern analysis in manufacturing process. The main idea of the proposed method is to visualize and identify various issues, including outliers that can occur during the manufacturing process on a daily basis. For this paper, we first provide a brief discussion of related methods that have been done towards the data visualization in manufacturing and describe their difference with the proposed method. Then, we describe the proposed method in details. We took a real-life example that represents an automobile part manufacturing process and demonstrated how the proposed approach could be applied to detect outliers in the manufacturing process.

2. RELATED STUDIES

In this section, we have several concepts to describe in more details such as visualization, abnormal data, analysis, etc. These concepts are essential for understanding the main contribution of the proposed method such as reducing the number of outliers.

Graph Visualization is the best feature for the handling of data and represents those to any 3D or 2D graph that meets the purpose and requirement defined by the user. For example, in recent US election, the database of people who voted was converted into visualization heat map. These features reduce and solve many problems that have occurred with real data. Information visualization focuses on data sets lacking inherent 2D or 3D semantics and therefore, also lacking a standard mapping of the abstract data into the physical screen space [8]. Data management systems using data mining [9] and visualization; it works on big data and uses data visualization [10], [11] to improve its performance. However, it still has limitation for their research on data. We have known that data can become a potential source of valuable information, and there must be analysis [12] using an algorithm to find the data that are useful for improving their future business. They use the application to visualize their data. In contrast, we apply more features for visualizing without the usage of applications.

Deep Learning algorithms are one promising techniques of research into the automated extraction of complex data representations (features) at high levels of abstraction. The authors in [13] use this method because of its high efficiency to handle large data, and the ability to mining and extracting significant patterns from big input data for decision making, prediction, etc. Further onto analyzing massive volume of data, big data analytics poses different unique challenges for machine learning and data analysis, such as format variation of the raw data, fast-moving streaming data, trustworthiness of the data analysis, highly distributed input sources, noisy and negative quality data, high dimensionality, scalability of algorithms, imbalanced input data, unsupervised and uncategorized data, limited supervised/labeled data. In this paper, we focus on data analysis based on big data, and will provide a position role to apply algorithm to improve performance, big data used for controlling massive amount of data in storage; this paper is not enough for users who are required to manage all the data and show it to the other users. As we mentioned before, large data is not comfortable for the users to understand well. So, we need to find an easier way to let the users understand their data with less complexity.

One important problem in mining data is extremely large databases [14]. This paper focuses on data analysis and performance, but it is still limited to visualization of the data. Modern technology makes people more quickly communicate with extensive data in real life including in society and computer technology. Especially the user needs a simple program with high efficiency for managing their data and this program must be accessed by web browser from anywhere. Therefore, we use both big data and visualization to increase the ability and optimize the efficiency in the manufacturing industry.

There have been some methods dedicated to the data visualization in the manufacturing process. Wells et al. [15] proposed a framework to visualize the variation patterns in manufacturing processes. The main concept of the proposed technique is to use computer-aided design (CAD) software tool and principal component analysis (PCA) [16] algorithm to perceive and visualize outliers in complicated manufacturing structures. Schedule visualization is one of the essential subjects in the area of industry, economics, and portraits. Jo et al. [17] proposed an interactive schedule visualization tool for manufacturing systems. The proposed approach has a useful resource reordering and obligations aggregation capabilities that make manufacturing schedule greater scalable, explorable and reschedulable. Augmented reality (AR) in manufacturing is one

of the effective approaches of visualizing throughout the overall methods [18]. Tang et al. [19] proposed a look at the effectiveness of the use of AR in manufacturing because it decreased the error rate by 82%.

The papers above have used diverse data visualization strategies with various degrees of fulfillment. The primary difference of the proposed approaches with these strategies is that we advise a calendar-primarily based approach to visualize the manufacturing process.

3. METHOD FOR ABNORMAL PATTERN ANALYSIS VISUALIZATION

In this section, we discuss the whole process of our proposed method program to apply to a visualization scheme with calendar heat map for abnormal pattern analysis in manufacturing process. As we mentioned before, data are complex and difficult to control without GUI. Otherwise, users do not have experience with the massive amount of data and analysis. We develop this interface to facilitate and optimize work process with much more efficiency. Through the proposed GUI, the user can check more details about data information without complexity. Specifically, it has an interactive interface with organizing layout and dynamic data. We divided eight options to the users in this GUI.

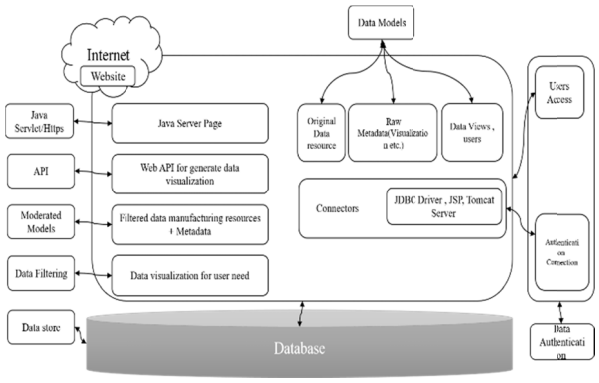

Fig. 1. The overall design of proposed system

Fig. 1 demonstrates the overall design of the proposed system. We divided the proposed system into several parts, so that it provides an easy access to manage our work and develop the program. It needs the internet to allow the user to reach our program; Java servlet is used to build a program that enables the developer to efficiently integrate the HTML elements with java code. Web API is fundamental during developing a website layout and making it run on the browser. Data filter first fetches the data from database and then apply the algorithm in order to filter the data that we are looking for. Data store has a high priority in controlling a vast amount of data and providing the data. Data models is a role for managing data resource to apply to our system and aid visualization to process with those data; this part focuses on client-side interface view on web browser. User access is provided to identify user match with our database, and check whether the user is registered in the system; it also provides high security to prevent attacks from outside. Data authentication provides security, such as giving permission to proper data to allow access to the server.

4. MANUFACTURING DATA VISUALIZATION USING CALENDAR HEAT MAP

In this paper, we propose an integrated manufacturing data visualization method using the calendar heat map. We demonstrate how to apply the proposed approach to car manufacturing process. The overall design of the proposed system is shown in Fig. 1. The proposed system illustrated in Fig. 1 has two parts, which are the front end and the back end. At the back end, the system contains a database that stores the manufacturing data and other modules to get the data to display to the front-end user. At the front end, the user is provided with an interactive interface that enables him/her to monitor the manufacturing process. The rest part of this section describes the implementation details. Thus, the user can use this calendar visualization to track all the information of the workers, method, material, machine, environment, error S/N, error detail and resource abnormal.

Let's consider that we want to visualize a car production process [20], [21]. The usage of the procedures is proven in previous subsections, and the output interface is shown in Fig. 2. The green square shapes demonstrate the daily workload in the production process. The darker colorings, such as red and black, display that there were overloads inside the process. We can consider those as outliers. Similarly, we can provide worker's information who worked every day, working methods and materials that have been used in manufacturing process, machine details and manufacturing environment for accumulating factors like temperature. One of the principal advantages of the proposed implementation is that it offers the interactivity to the process manager. For example, the manager can click on any square shape to see the information on the manufacturing technique for that typical day. It offers flexibility to the end user to control the entire manufacturing process.

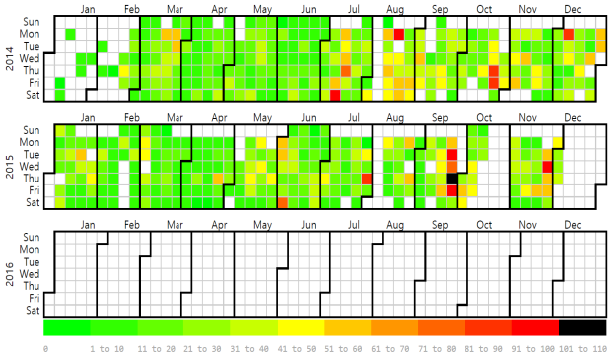

Fig. 2. Visualization using calendar heat map

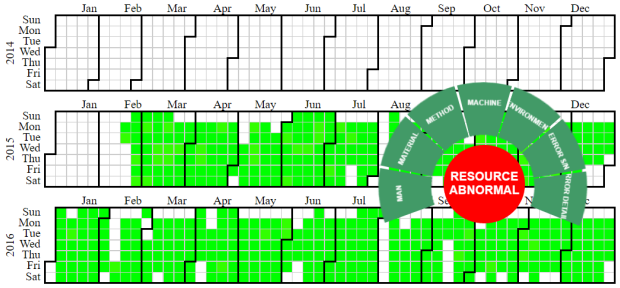

Fig. 3. Visualization calendar heat map with the menu item

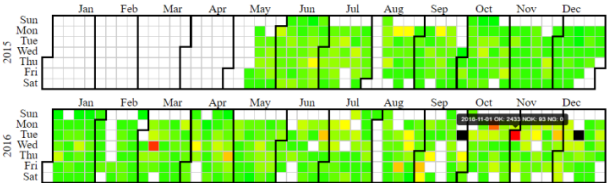

Fig. 4. Visualization heat map with tooltip information

To analysis resource abnormal data, we apply a decision tree algorithm which is one of the most widely used and practical methods for inductive inference over supervised data. Decision tree [22] represents a system for classifying categorical data which is totally based on their attributes. Because we lack information for the next days to come, we want to make sure our proposed method can facilitate their manufacturing industry in predicting the future based on the data. In this research paper, we use this algorithm to analyze data of car manufacturing industry to predict data. As we have mentioned already, it is not easy to use our data in our system; in this algorithm, the problem of the raw data has been solved. In the industry, there are many dynamic data that grow rapidly in daily process. It is a burden to manage those data without any help from other algorithm or software. Especially, we can use its algorithm with many program languages to analyze our data. Moreover, it provides the best feature for us that allow our data to be represented on the two-dimensional graph as shown in Fig. 5. Therefore, we decided to choose decision tree algorithm for optimizing our process with more efficiency and prediction data in the future.

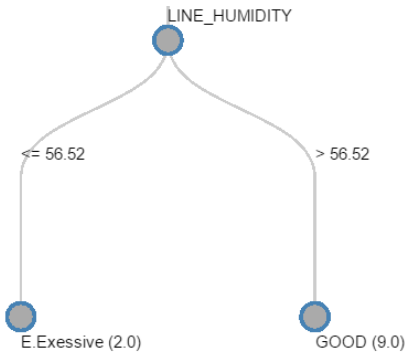

Fig. 5. Weather Decision tree

Minimizing the global error of a decision tree with a fixed structure is a non-convex optimization problem. The problem which is of constructing a decision tree with a fixed number decisions to correctly classify two or more sets.

5. IMPLEMENTATION

In this section, we discuss the implementation details of our proposed system. First of all, we initiated the primary interface of the graph that is shown to the user. It is the main GUI to handle a large scale of data and various functions. It includes choosing the shapes and colors of the calendar and determining the scales. The screenshot of the code used for initialization of the calendar map is shown in Fig. 6. It was developed by using JavaScript.

```
var year, OK, NOK, NG;
var open = false;
var width = 900, height = 105, week_days = [ 'Sun', 'Mon',
        'Tue', 'Wed', 'Thu', 'Fri', 'Sat' ], month = [ 'Jan',
        'Feb', 'Mar', 'Apr', 'May', 'Jun', 'Jul', 'Aug', 'Sep',
        'Oct', 'Nov', 'Dec' ]
cellSize = 12;
var percent = d3.format(".1%"), format = d3.time
        .format("%Y-%m-%d");
var color = d3.scale.quantize().domain([ 0, 11 ]).range(
        d3.range(11).map(function(d) {
            return "q" + d + "-11";
        }));
console.log(JsonData);
svg = d3.select(".calender-map").selectAll("svg").data(
        d3.range(2013, 2017)).enter().append("svg").attr(
        "width", '100%').attr("data-height", '100%').attr(
        "viewBox", '0 0 900 105').attr("class", "RdYlGn")
        .append("g").attr(
                "transform",
                "translate(" + ((width - cellSize * 53) / 2)
                        + "," + (height - cellSize * 7 - 1)
                        + ")");
svg.append("text").attr("transform",
        "translate(-35," + cellSize * 3.5 + ")rotate(-90)")
        .style("text-anchor", "middle").text(function(d) {
            return d;
        });
for (var i = 0; i < 7; i++) {
    svg.append("text").attr("transform",
            "translate(-5," + cellSize * (i + 1) + ")").style(
            "text-anchor", "end").attr("dy", "-.25em").text(
            function(d) {
                return week_days[i];
            });
}

rect = svg.selectAll(".day").data(
        function(d) {
            return d3.time.days(new Date(d, 0, 1), new Date(
                    d + 1, 0, 1));
        }).enter().append("rect").attr("class", "day").attr(
        "width", cellSize).attr("height", cellSize).attr("x",
        function(d) {
            return d3.time.weekOfYear(d) * cellSize;
        }).attr("y", function(d) {
    return d.getDay() * cellSize;
}).datum(format);
var legend = svg.selectAll(".legend").data(month).enter()
        .append("g").attr("class", "legend").attr(
                "transform",
                function(d, i) {
                    return "translate(" + (((i + 1) * 50) + 8)
                            + ",0)";
                });
legend.append("text").attr("class", function(d, i) {
    return month[i]
}).style("text-anchor", "end").attr("dy", "-.25em").text(
        function(d, i) {
            return month[i]
        });
svg.selectAll(".month").data(
        function(d) {
            return d3.time.months(new Date(d, 0, 1), new Date(
                    d + 1, 0, 1));
        }).enter().append("path").attr("class", "month").attr(
        "d", monthPath);
```

Fig. 6. Implementation of GUI Calendar heat map

5.1 Calendar Data Implementation

Data have been used with many options that depend on data and user's needs. Before we can use those data on visualization, we must develop a primary standard 2D graph that can combine data with visualization. This section shows how to develop a graph with a programming language that we use to create 2D calendar representation of data. We used

JavaScript to handle the code getting data, and HTML syntax to make graph interface that is known as 2D.

We retrieve the data into JSON array and follow d3.js features to visualize the data. Fig. 3 shows the implementation of calendar data. We used d3.nest() function of d3.js library so one can organize the data. Also, we used rollup() function to mix the data into multiple data points as shown in Fig. 7.

```
(function() {
    var data = d3.nest().key(function(d) {
        return d.workdate;
    }).rollup(function(d) {
        return d[0].total_data - d[0].real_ok;
    }).map(JsonData);
    console.log(d3.nest().key(function(d) {
        return d.workdate;
    }).rollup(function(d) {
        return d[0].total_data - d[0].real_ok;
    }).map(JsonData));

    var RealNG = d3.nest().key(function(d) {
        return d.workdate;
    }).rollup(function(d) {
        return d[0].real_ng;
    }).map(JsonData);

    var RealOk = d3.nest().key(function(d) {
        return d.workdate;
    }).rollup(function(d) {
        return d[0].real_ok;
    }).map(JsonData);
    rect.filter(function(d) {
        return d in data;
    }).attr("class", function(d) {
        if (data[d] === 0) {
            return "day " + color(0);
        } else if (data[d] > 0 && data[d] <= 10) {
            return "day " + color(1);
        } else if (data[d] > 10 && data[d] <= 20)
            return "day " + color(2);
        } else if (data[d] > 20 && data[d] <= 30)
            return "day " + color(3);
```

Fig. 7. Calendar Data Implementation

5.2 Calendar Item Menu

The calendar item menu can be used to provide the information about data in the calendar view map. The user can click on one of the items to show inclusive information of men (worker detail), method, material, machine, and so on. It demonstrates a part of the code that is created for calendar item menu. This function is useful for managing data that is used by the user. It provides 8 item menus to access data from the real server. These features look simple and easy to use. Moreover, we can call these functions just by clicking on a specific point of the calendar heat map.

5.3 Item menu data implementation

After we created our GUI item menu we have front-end interface for the user; we develop back-end coding to connect our GUI to real data by using Java code and HTML. There are many ways that we can discuss implementation by combining both Java and HTML to work together. In this part, we solved this issue by using coding.

6. IMPLEMENTATION RESULTS

This section describes our implementation results by the designed application which can control all the data and analyze, do clustering, and find outliers. Because many issues took place in many sectors of manufacturing industry by lacking control of data and showing weak performance in chain produce of product. We decided to develop this program based on those issues and their data to improve and optimize the process with more efficiency in the future. Data are growing every day; it is hard to control without any help from software or tool. We make analysis clear about data according to the user's requirement. Therefore, we can help their work to be more efficient than before. They get the best software management that provides them with benefit in the future. In Fig. 8, we developed a function combined with heat map visualization, which works based on data and fetches matching data with a particular date. So, the user can see data by each date-time and can change specific information in each table.

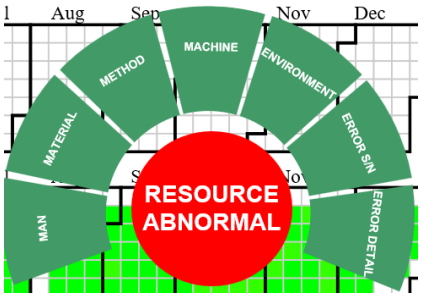

Fig. 8. The user interface to visualize 4M1E

We have developed functions to manage all the data of machines with high efficiency and flexibility. Fig. 9 shows the information of a machine. This feature allows the user to find out about the data that matches with date based on a table which is selected. Fig. 9 shows details about machine information and retrieved data from the database. It can provide such details to the user. We developed this GUI to make it easier to control large information in this system. We filter the data that are needed.

In the manufacturing process, we did not only focus on the process of producing the product. We considered about the environment because the environment is important for the whole manufacturing. We do not know clearly about what will happen when it is raining. Something might happen like a storm or any other natural disasters.

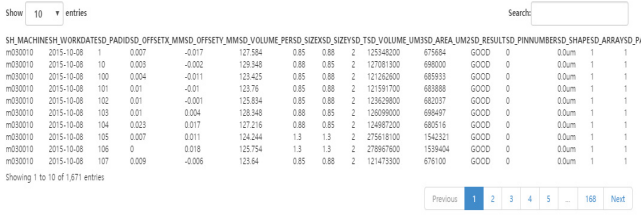

Fig. 9. A visualization example of a machine data

Fig. 10 will show more in detail about information and the environment and focuses on the environment which provides details to the user; it also helps the user to make a decision about processing with a machine such as a temperature so that we can make a balance with machine and temperature. It also has benefit for processing both inside and outside of manufacturing. So, we provided information to the user which would help the user to prevent problems caused by natural phenomenon.

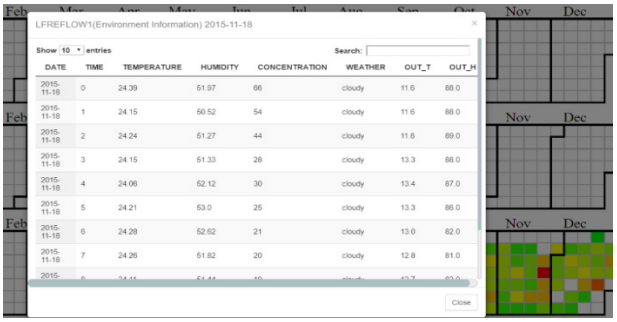

Fig. 10. A visualization example of an environment data

There are many workers in manufacturing who control machine dependent on their position and specific machines to manage. In this function, we support the user to check daily on each worker's process and work information details about the date as shown in Fig. 11.

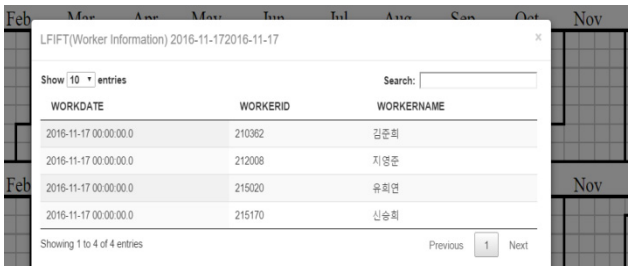

Fig. 11. A visualization example of a man data

The most important thing in the manufacturing industry is focusing on the quality of the products, so we must make sure that their product is good with high efficiency. This problem is related to the good or bad quality of processing the product. So, we built this function to allow the user to check the database and find some product that has low and high quality. Otherwise, manufacturing processes daily; the system can allow you to check daily if you want. As shown in Fig. 12, you can find specific product's information in detail.

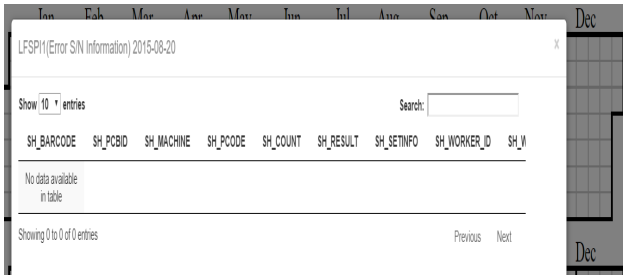

Fig. 12. A visualization example of an error S/N data

Many industries try to make their product with great quality, but it has two possibilities that is having an error and not having an error. Therefore, all the manufacturing industries have many machines that work, and we can collect information from those activities, and find errors. Thus, we can apply this issue to our system that handles all the information about errors and figures out what the problem is. As shown in Fig. 13, we can see in more detail what the cause of the problem that has occurred is.

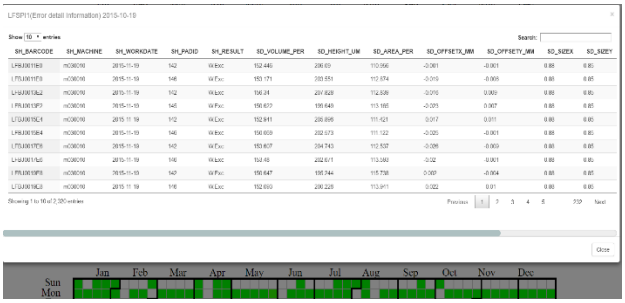

Fig. 13. A visualization example of an error detail data

We analyzed the real data which was developed during manufacturing products. Through the analyzed data, they want to know the quality of goods as well as the percentage of good and bad products. We used decision tree algorithm to do it, and one of data mining algorithms to classify them. Fig. 14 shows a visualization example for detecting abnormal reasons on a bad product.

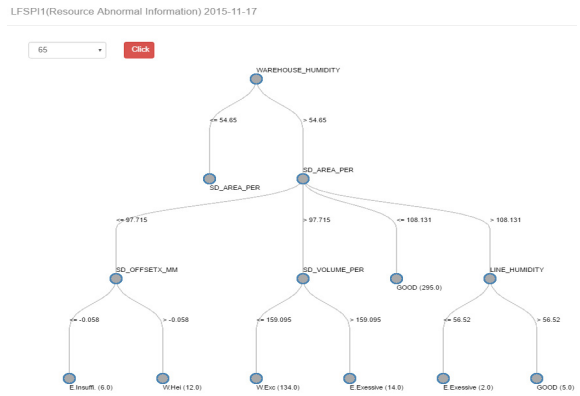

Fig. 14. A visualization example of resource abnormal analysis results by using decision tree method

7. CONCLUSION

In this paper, we have proposed a visualization scheme with calendar heat map for abnormal pattern analysis in manufacturing process method. We have got precisely all the processes and then provided the details with stated implementation. We have shown the cutting-edge example with the usage of the proposed method in car manufacturing process. The proposed method can offer the data within the manufacturing procedure and assist in discovering problems and outliers.

Even if we provided a trendy detailed overview of the state-of-the-art techniques inside the subject of manufacturing

visualization procedure, we could not conduct the performance assessment. In the future, we are going to perform experiments that allow that the proposed method to manage a large quantity ultra-modern data.

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