Drinking Behaviour Patterns in Dairy Cattle

Negar Sadrzadeh and Arash Kamyabi

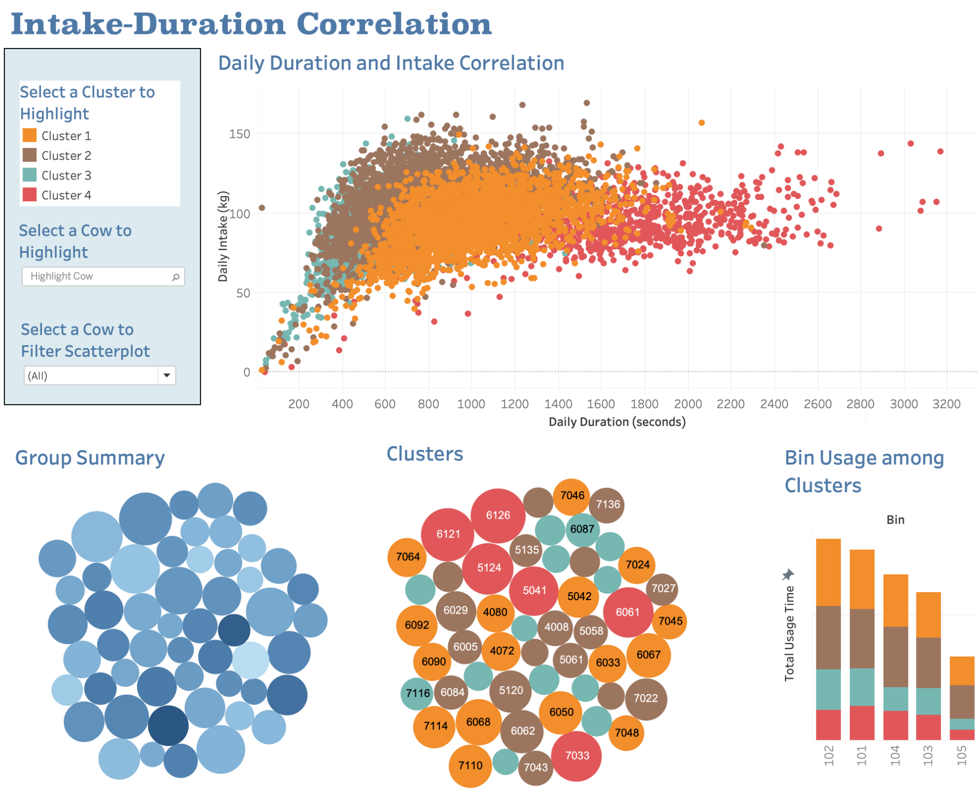

Fig. 1: Overview of the interactive dashboard designed to visualize drinking behavior of dairy cattle. The control panel (top left) allows the user to highlight and filter the plots to explore the information for individuals, clusters, and group. A scatter plot (top right) is used for the visual encoding of the correlation between the daily duration and intake. Two bubble plots (bottom left) are summarizing the drinking behaviour of individuals in the group. The stacked bar chart (bottom right) shows a summary of how group and clusters use different water bins.

Abstract—We implement a new interactive visualization dashboard for investigating the drinking behavior of dairy cattle. Our proposed solution allows users to discover, compare, and summarize the dataset collected by UBC Dairy Education and Research Center on their dairy cattle. Our visualization includes interactive idioms that reveal relationships between drinking duration and water intake. Users can compare individual drinking behavior of the cattle and analyze potential seasonality patterns. We hope our visualization tool allows UBC researchers to better understand their cattle drinking behavior and gain insight into optimal decisions on water access and housing.

Index Terms—Dairy Cattle, Drinking Pattern, Information Visualization

1 Introduction

As sustainable consumption of freshwater resources is becoming a subject of increasing importance, dairy farms are incentivised by both environmental policymakers and consumers to re-evaluate their best management practices. In agriculture, best management practices for use of freshwater are defined as practices that minimize pollution entering surface waters [3], and in general described as promoting sustainable use of resources without loss of benefits. Water is also a key nutrient for dairy cows and water deprivation can adversely affect their health, behavior, and performance [7]. The negative effects of water deprivation include an increase in hematocrit and blood urea [2], lower respiratory rate, and more aggressive behavior around waterers [13]. As such, there is an increasing demand to better understand the drinking behavior of dairy cows.

Ad libitum access to water, also known as free access, is known to promote to dairy cattle welfare and production. However, not every dairy farm has the appropriate environment to support ad libitum access. Moreover, farmers can't evaluate the efficiency of their drinking system based only on herd level drinking behaviour since this behaviour can vary across individual cows and each cow responds differently to changes in feed, environment and social grouping [17]. Therefore, for optimal decisions on water access and housing, individual differences should also be considered. Although there is considerable literature on

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the prediction of water intake, there has been a very few studies on the drinking behavior of dairy cattle. While it is generally accepted that dairy cows require large amounts of water, there is little consensus on how often and when dairy cows drink. There is even fewer studies on the drinking behaviour of the individuals and how their water intake and behaviour are affected by their housing systems [12]. These questions must be properly addressed to improve housing, management decisions, and water supplies in dairy farms.

Fortunately, technological advancements have allowed for widespread deployment of sensors to capture high-resolution data that can provide insight into individual behaviors. For example, InsenTec system, shown in figure 3, is a system for monitoring the feeding and drinking behaviour of group-housed cows [6]. In a longitudinal study conducted at the UBC Dairy Education and Research Centre (DERC), a pen of 48 lactating Holstein cows with access to 24 feed bins and four water bins were studied for ten months. The dataset collected from the InsecTec system during this study can provide constructive insight into the behavior of individual cows as well as the herd.

The goal of this project is to design a visualization tool to analyze this dataset and discover patterns in the cattle drinking behavior. A visualization tool is necessary for our project as it allows UBC researchers to discover, compare, and summarize the drinking behavior of the cattle in a way that other purely computational techniques cannot offer. While statistical characterization of this dataset can produce descriptive statistics, this approach prevents exploring the dataset structure in detail and finding patterns.

Fig. 2: An InsenTec bin: the bins are normally closed and when a cow gets close to the bin for eating or drinking, the bin opens only after the cow is identified. The identification happens with the RFID ear tags. Then the cow can enter and use the bin. The cow identification number, the time of entrance and exit and, the amount of intake are all recorded for each visit.

2 Related Works

In this section, we explore existing literature on drinking behavior of cattle as well as a recent visualization tool 'Peek-a-Moo' designed to visualize the data collected from the InsenTec system. We evaluate the approach taken by 'Peek-a-Moo' and discuss other strategies for for time-series data visualization.

2.1 Existing Literature on Cattle Drinking Behaviour

There has been considerable research on factors that affect free water intake. Some of the most frequently cited parameters include dry matter intake [8, 10], milk yield [14], dry matter content , and different expressions of climate conditions [14, 16]. Several authors also noted that although restricting water access results in cattle drinking more at each drinking opportunity, their total water intake will be lower and insufficient [9, 18, 19]. The effects of drinking behavior on performance of cattle have also been the subject of research. Notably, a systematic literature review was conducted to explore the relationship between drinking frequency and cattle performance [21]. This review highlighted a number of important gaps in the literature where future work is required to better understand the optimum drinking frequency of cattle and effects of water availability on health, welfare and performance. While this body of knowledge can help predict water intake of dairy farms, it does not address the drinking behavior of the dairy cattle such as frequency and duration.

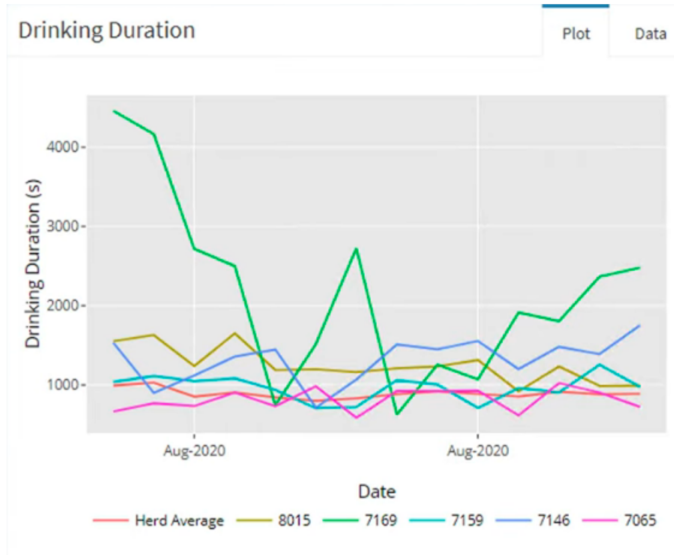

Fig. 3: Peek-a-Moo visualization of the drinking data collected by the InsenTec system. Users have the option to select individual cows to be displayed along with the 'Herd Average' statistic. Peek-a-Moo is limited to visualizing the total daily duration of the cattle in this time-series line graph.

In a paper released by the American Dairy Science Association, [4] investigated the drinking behavior of dairy cows and the links between behavior and water intake. Although this work is more aligned with the subject of this study,the authors took a statistical approach to the problem with minimal visualizations. Moreover, the statistics represent the herd as whole and give little insight into the individual behavior of the dairy cows.

2.2 Existing Cattle Data Visualizations

As discussed, drinking behavior of cattle depends on numerous factors and this behavior can be different for every cattle herd. Thus, the Dairy Education and Research Centre (DERC) at UBC has collected a database of information on its dairy cattle to better understand their drinking, eating, and even social behavior. In a recent project, a team of students from the UBC Master of Data Science collaborated with the DERC to develop a data visualization tool to analyze the data on their cattle herds. The tool, named 'Peek-a-Moo', provides a customizable and interactive dashboard that shows simplified summaries of cattle behaviour [1]. According to Peek-a-Moo's website, researchers can interact with the dashboard to view:

- Timelines of individual cow's behaviour throughout the day along with a "herd average"
- Social networks that display relationships between cows
- Feed bin graphs that measure dynamic feed and water distributions across all bins
- Warning messages for bin malfunction and cows with abnormal level of feed or water intake

While Peek-a-Moo is simple to use and effective at visualizing a wide range of statistical data, it has intrinsic limitations on the depth and detail of its visualizations. In the case of investigating cattle drinking behavior, users are limited to a time-series line graph of drinking duration as shown in figure 3. Unfortunately, such simple visualizations fail to give insight into in-depth topics such as the correlation between drinking duration and water intake, or daily drinking patterns.

As such, there is a need to develop a new visualization tool to better take advantage of the comprehensive data collected by the DERC and allow UBC researchers to analyze drinking behavior of the dairy cattle

Attribute	Type	Description	Range/Unique Values	Scale
Cow	Categorical	A unique 4 digit number assigned to each cow	53	-
Start	Ordinal	The date and time when the visit starts	5/7/2020 - 3/5/2021	-
Duration	Quantitative	The time spent at the bin	0-250	seconds
Intake Amount	Quantitative	The amount of water consumed	0-30	kg
Bin	Categorical	The number of water bin	5	-

Table 1: An overview of the dataset collected by the InsenTec System

Attribute	Type	Description	Scale
Daily Duration	Quantitative	Total duration of visits during the day	seconds
Daily Intake	Quantitative	Sum of all water intake during the day	kg
Average Daily Duration	Quantitative	Average of daily duration of visits all days	seconds
Average Daily Intake	Quantitative	Average of daily water intake for all days	kg

Table 2: An overview of the derived data from the InsenTec drinking dataset

more efficiently and thoroughly. As our data comprises time-series drinking behavior of the dairy cattle, we studied existing time-series data visualization strategies such as ATLAS [5], Stack Zooming [11] , and Cluster and Calendar [20] based visualizations. While most of these solutions were not appropriate for our dataset, we were particularly inspired by Cluster and Calendar and implemented a clustering-based approach for one of our idioms.

3 Data and Task Abstraction

3.1 Data

Throughout the trial cows were housed in a dynamic group of 48 animals in a pen with access to 4 water bins. A total number of the 166 cows were watched during the trial. The dataset collected by the InsenTec system is static and sequential consisting of 182951 data points ordered by time. The dataset is in the form of a table and each item contains the information regarding a cow visiting a water bin for drinking water. The attributes of each visit are noted in Table 1. From this dataset, we also derived additional data, shown in Table 2 that will also be visualized in our solution.

3.2 Task Abstraction

The main goal of our visualization tool is to allow researchers at the DERC to take full advantage of the dataset collected and comprehensively analyze the dairy cattle drinking behavior. As such we aim to incorporate all the attributes of our dataset in an interactive visualization in an informative manner. We can break down our project goal into three main tasks.

3.2.1 Intake-Duration Correlation

Users should be able to explore the correlation between the Daily Duration and Daily Intake. This task involves discovering similarities and patterns at a herd-level, as well as for individual cows. Our visualization should allow clustering or grouping of cows that show similar drinking behavior with their daily duration and daily intake. For example, a group of cows that spent a lot of time at the water bins but only intake low amounts of water should be grouped together. Users should also be able to compare this correlation across the different groups as well as across individual cows.

3.2.2 Seasonality

This task aims to explore the correlation between time and visits. Users should be able to discover seasonality of the data and the distribution of visits with respect to time. For example, at what time of day are the visits most frequent and least frequent? Does an individual cow visit the water bins at the same time every day? Does visit frequency increase during summer compared to winter? Users should also be able to compare visiting frequency between individual cows and discover similarities between herd behavior and individual behavior.

3.2.3 Individual Behavior

This task focuses on visualizing individual drinking behavior of the cows. The aim is to present the change in various aspects of drinking behaviour over time and explore the behaviours that are consistent over time. This may vary among individuals and the aim of this task is not to only compare individuals, but to discover trends within each cows drinking behaviour.

4 Solution

The solution that we propose is a visualization design consisting of two pages:

- Intake-Duration Correlation
- Individuals

Each page is an interactive dashboard where the users can view and explore the dataset based on their goals. The reasoning to separate the visualizations into two pages was based on the display limit, information density and human memory. To avoid high information density, one page addresses the first task called ”Intake-Duration Correlation” described in the *Task Abstraction* section and the second page addresses the ”Seasonality” and ”Individual Drinking Behaviour” tasks. Both dashboards include multiple idioms to communicate the information effectively to the users. We did not want to go beyond two pages to limit the constrains of human memory in correctly relating idioms addressing the same question when they are displayed separate pages.
To take full advantage of digital visualization, we decided to use interaction for both designs because it makes the models more flexible, powerful and allows user to explore the data more freely. A downside for this interactivity is that the control panel occupies valuable screen space and users may not interact with the idioms as we intend. However, this dataset is being presented to domain experts for the first time through these dashboards and the models need to be as flexible as possible in visualizing the data to address the many questions that may arise after exploring the data. In the following sections, we will describe our design choices more in details for each of the two pages.

4.1 Intake-Duration Correlation

This page, shown in figure 1, aims to present the data to address questions regarding the correlation between the time cows spend in the water bins (duration) and the amount of water that they drink (intake). More details about this design is described in the What-Why-How platform in table 3. It consists of one control panel, one scatter plot, two bubble plots and one stacked bar chart.

4.1.1 Control Panel

The control panel includes three tiles. The first one is to highlight the clusters and the user can activate it when selecting one cluster by clicking on it. We have applied linked highlighting so by selecting one cluster the corresponding data points in all 4 plots will be highlighted. This idiom provides the user with various information about each cluster and individuals at the same time, see figure 4. Also, the user can search, highlight or filter multiple cows by selecting them in the two dropdown menus to investigate their behaviour.

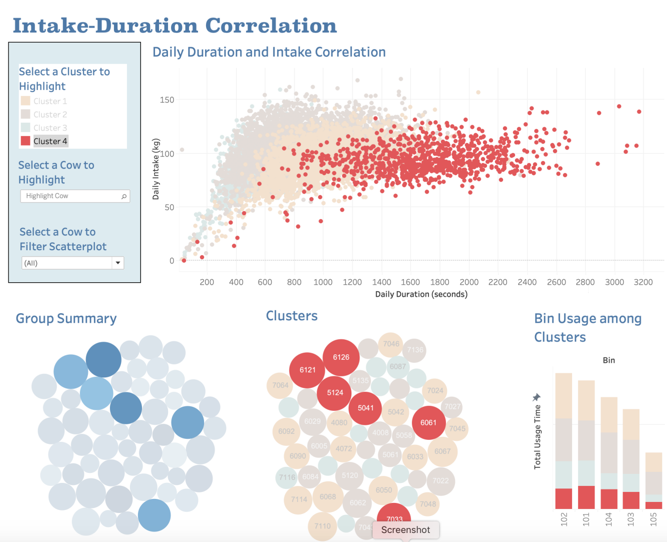

Fig. 4: Linked highlighting allows the user to explore different information about each cluster or individual at the same time.

4.1.2 Daily Duration and Intake Correlation

We chose a scatter plot for the visual encoding of the correlation between the daily duration and intake. Each mark on this scatter plot represents the total drinking duration and intake of one cow in one day.

System	Duration-Intake Correlation
What: Data	Table including the information on visits to the water bins by cows 2 categorical, 2 quantitative
Why: Task	Explore the correlation between the Duration and Intake; Find trends, distribution, correlation, clusters. Explore bin usage.
How: Encode	Scatterplot, colored by conjectured clustering
How: Encode	Scatterplot (bubble plot) with separate categorical regions, not aligned or ordered
How: Encode	Stacked bar chart
How: Manipulate	Select
How: Manipulate	Unconstrained navigation, item reduction, zoom
How: Facet	Juxtapose and coordinate multiple Side-by-Side views; Linked highlighting; Share data
How: Reduce	Filter
How: Reduce	Embed
Scale	Thousands

Table 3: What-Why-How platform for the Duration-Intake Correlation dashboard

The marks are filled circles and a colour channel is used for encoding the attribute of cow’s cluster. We found that a scatter plot is the best choice as the task is related to finding the trend and correlation and the scale is around 9000 data points.

4.1.3 Group Summary and Clusters

Two Scatter plots with separate categorical regions, not aligned nor ordered, show an overview of the drinking behaviour of the group (figure 1). Each circle represents a cow and the circles are size and color coded based on the average daily drinking duration and average daily water intake, respectively. The hue on the other bubble plot represents the cluster to which each cow belongs to. These plots, also known as bubble plots, limit the comparison between the pairs based on their size. However, our goal isn’t to compare pairs of cows based on only the size (duration) or the colour (intake). With this visual encoding, we aim to provide an overview of the group and the clusters. The same plot with two different color-codings, intends to better display the differences and similarities in clusters. An alternative to the bubble plot is a treemap. We preferred the bubble plot over the treemap because the differences in circle sizes are more recognizable to the human brain than rectangles next to each other. This was a result of a small evaluation done among the animal welfare program students.
We chose the hue for the clusters from the colors with high saturation, as the number of clusters are low and the covered area is not big.

4.1.4 Other Features

We implemented bidirectional linked highlighting in this dashboard so the user can select any cow in each of the plots and the other plots will be highlighted accordingly. This feature helps the user explore faster and keep track of the information easier. Also, geometrical zooming toolbar is displayed by hovering on the plots, providing the user the ability for unrestricted navigation, see figure 5.

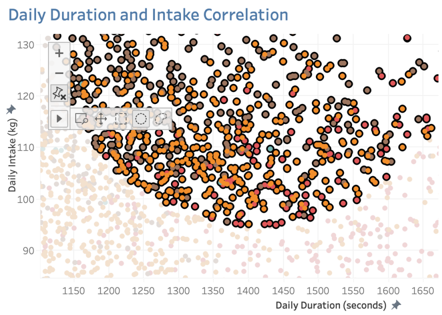

Fig. 5: Navigate toolbar provides the user the ability for unrestricted navigation and geometrical zooming

Moreover, we chose an embedding idiom for reducing the amount of information in the screen. The information for each cow including the cow number, cluster, average daily intake and duration in addition to a bar chart visualizing bin preference are elided from the bubble plot and displayed in a small window when hovering over each cow, see figure 6.

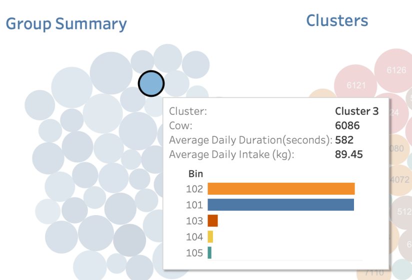

Fig. 6: Data is elided from the view and embedded in another window which appears by hovering on each circle.

4.2 Individuals

In this page, we aim to allow the users to analyze the drinking pattern of individual cows and compare it with other cows and the herd behavior. Similar to the "Intake-Duration Correlation" page, there is a control panel that allows the user to select an individual cow using it unique ID as well as the desire time interval. A scatter plot is used to visualize the intake-duration correlation of the selected cow for the same reasoning mentioned for the previous page. However, in this page, the color channel is used to encode the bin used for the visit. The bin preference of the cows are also visualized with a bar chart at the top-right of the page as seen in figure 7. To allow for discovery of patterns in the visiting frequency, we deployed a heat-map to visualize the visiting density of the cow with respect to day and time of day. This individual heat-map is displayed next to the herd pattern to facilitate comparison between individual cows and herd behavior. Specific scenarios of use is further discuss in the *Results* section.

5 Implementation and Milestones

The original dataset from the InsenTec system was shared with us in an RDA file format which is supported by R, a statistical analysis and graphing program. During the data cleaning and organization process, we exported the drinking data from the dataset as an CVS file. We used Tableau to prototype our initial set of visualizations which we refined over time into our final interactive dashboard design. We took advantage of Tableau's built-in clustering algorithm to cluster cows with similar drinking duration and water intake patterns. Table 4 provides a detailed timeline of the tasks we completed throughout our project and their approximate duration.

6 Results

6.1 Scenario 1

In dairy farms with normal water troughs, it is not possible to monitor the amount of water individuals drink. This is an important issue because low amount of water intake can be an indicator of health problems and can result in poor performance.
Users can use the Duration-Intake Dashboard to observe and monitor the cluster of cows that have have low intake and duration. They are also able to analyze the behavior of individual cows in that cluster in the Individuals page to observe their visiting frequency. For example, in figure 7, the user has access to all the drinking data of cow ID 6086. The individual heat map shows the visiting frequency of the cow peaks around 8AM and 5PM most days. In fact, the visiting behavior of this cow is in sync with the herd average shown in the adjacent heat map. This pattern occurs because the dairy cows are often milked at 8AM and 5PM, after which they commonly visit the water bins.

6.2 Scenario 2

We want to know if there are cows who occupy the bins more than others and limit the access to water for others. By taking a look at the dashboard, and exploring different clusters, we can notice that the marks for the cluster number 4 in the bubble plot are larger in size. This size difference is an indicator that these cows spend more time in the specified bins (figure 8).

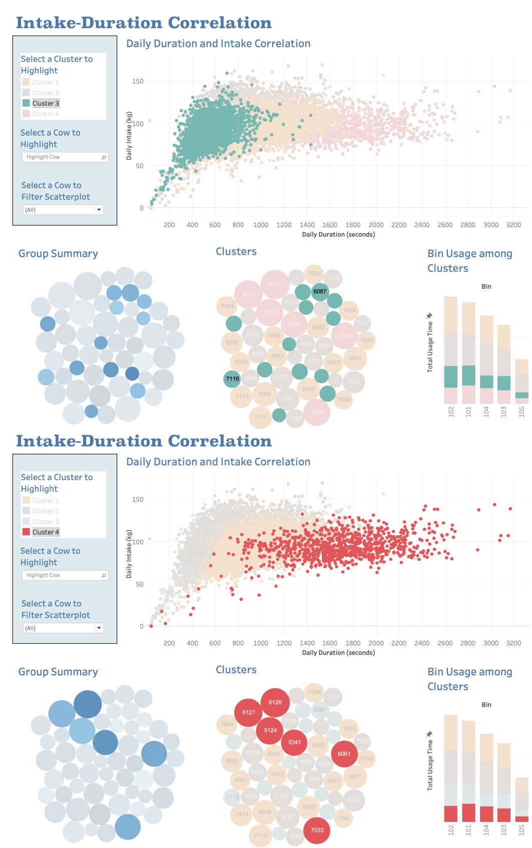

Fig. 8: Highlighted clusters (a) Cluster 1, (b) cluster 4

Taking a closer look, we can notice that these large circles are not darker than the others which means these cows, on average, spend more

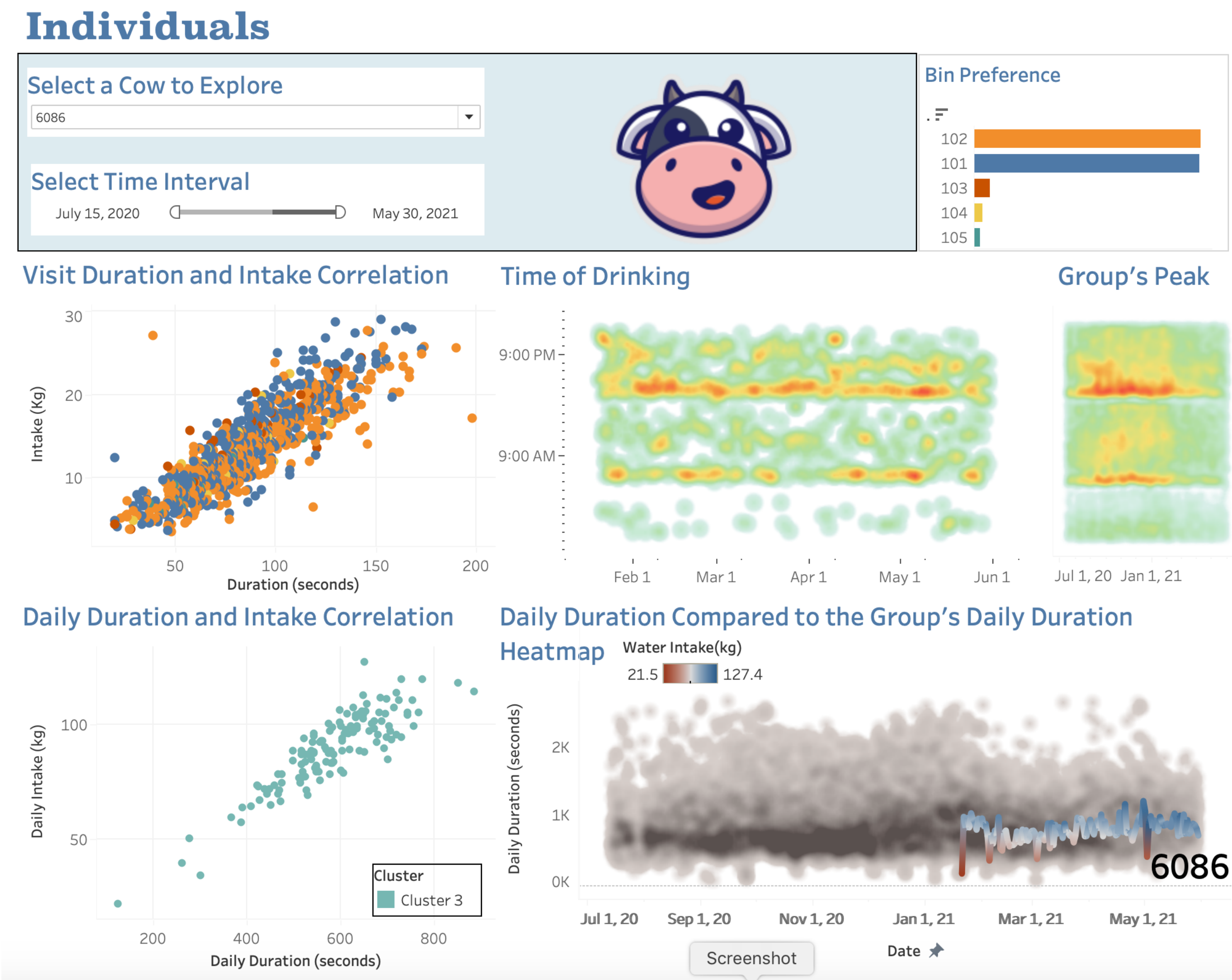

Fig. 7: Individuals Dashboard

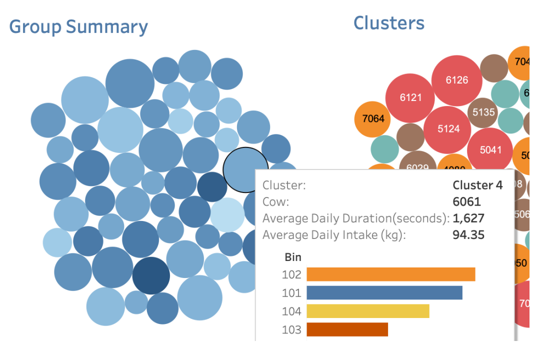

Fig. 9: Hovering over larger circles

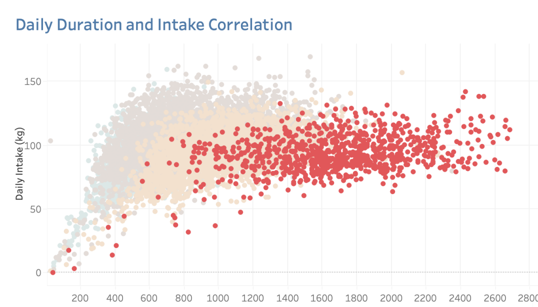

Fig. 10: The cluster 4 data points. The ratio of duration to intake for these cows is higher than other clusters

time in the water bins but they do not drink more, see figure (figure 9).

We can then look at the scatter plot and notice that the data points for these cows also confirm the higher ratio of duration to intake for these cows. As such, we can conclude that the cows in cluster 4 are spending a lot of time in the water bins without drinking water which is a cause for further investigation.

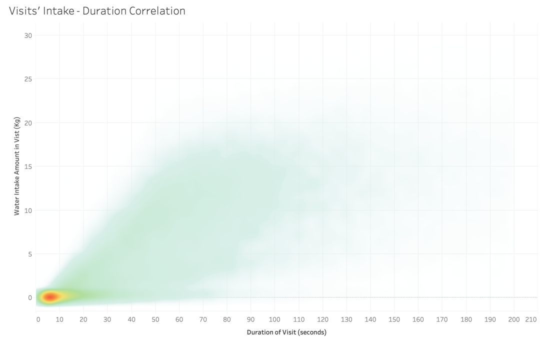

Fig. 11: Heatmap of the visits. There is a high density of short visits.

7 Discussion and Future Work

We have proposed two interactive dashboards for exploring a dataset containing 10 months of all drinking events for a group of Holstein dairy cows. The first dashboard aims to help the user explore the relationship between the drinking duration and intake. This dashboard can effectively present the correlation between daily drinking duration and intake for individuals and the whole group. It also allows the user to discover cows with similar drinking behaviour and compare the different patterns of duration-intake correlation between different clusters. However, this dashboard does not present the visit level correlation. We decided not to include the visual encoding for visit-level duration-intake correlation in this dashboard because of the high density of short events, figure 11. These events may contain important information regarding the welfare and health of the cows, or may be a part of the drinking behaviour for some cows. So, we decided not to filter them out and leave the visit-level visual analysis for future work.

We also plan to cluster the visits and explore the distribution of visits for each cow in different clusters. We can then compare the results to the daily level and decide the scale that represents better the behaviour.

Our second dashboard shows different information about each individual. Based on very limited feedback from domain experts it might be essential to have this high density of information for exploring the data for the first time. However, for further tasks, the current information density might be extra.

During the data collection trial, the monitored group had net stayed stable and the group composition had changed on a weekly basis. For example one cow has been monitored from Jan 1st to May 1st, whereas another cow has been in the experiment from Aug 1st to Jan 1st. Accordingly, the dataset contains events from different number of days and time windows for different cows. This limits the comparisons between individuals. Additionally the data aggregation should eliminates the effect of number of days. In this study we are using average which may cause the loss of some information. A different data aggregation may lead to different results. This is another topic which requires further study.

Last but not least, we plan to do the evaluation and interactively refine the design, based on the 4 level nested model [15].

8 Conclusion

In this paper, we discussed our new interactive visualization tool for analyzing a dataset on dairy cattle drinking behavior collected by UBC DERC. Our main goal with this tool is to comprehensively analyze the valuable data which involves tasks of discovery, comparison, and summary. The interactive idioms allow users to explore the relationships between drinking duration and water intake of individual cows alongside the herd average. Additionally, our visualization dashboard allows discovery of seasonality patterns amongst individual cows and the herd. We hope UBC researchers can utilize these visualizations to gain a better understanding of their dataset on cattle drinking behavior and gain insight into best management practices for dairy cattle.

Acknowledgments

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Estimated Date of Completion	Actual Date of Completion	Task	Estimated Hours	Actual hours
Sept 29, 2021	Sept 29, 2021	Project pitch	4	NS: 4 AK: 4
Oct 21, 2021	Oct 21, 2021	Write first draft of project proposal	10	NS: 8 AK:5
Oct 25, 2021	Oct 25, 2021	Data Exploration in Tableau	5	NS: 6 AK: 2
Nov 10, 2021	Nov 10, 2021	Background research on related work with similar tasks	6	NS: 2 AK: 8
Nov 10, 2021	Nov 12, 2021	Data management and cleaning	6	NS: 4 AK: 0
Nov 10, 2021	Nov 12, 2021	Brainstorm possible solutions in Tableau	8	NS: 8 AK: 3
Nov 16, 2021	Nov 16, 2021	Update proposal to include feedback	12	NS: 4 AK: 10
Nov 16, 2021	Nov 20, 2021	Prototype a vis tool to show the data trends	10	NS: 12 AK: 5
Dec 12, 2021	Dec 17, 2021	Finalize visualizations	10	NS: 10 AK: 2
Dec 15, 2021	Dec 15, 2021	Create content for final presentation and practice	10	NS: 7 AK: 10
Dec 17, 2021	Dec 18, 2021	Prepare final report	18	NS: 15 AK: 15
-	-	Learning Tableau	10	NS: 10 AK: 3
-	-	Synchronous and Asynchronous Communication	-	NS: 15 AK: 15

Table 4: Milestones and task breakdown with initial expected hours and actual individual hours put into each task [NS: Negar Sadrzadeh, AK: Arash Kamyabi]

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