Georgia Institute of Technology

OMSA Practicum Final Report

AudioT Poultry Welfare and Live Operations Visualization Dashboard

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Introduction

About AudioT

AudioT is a venture established in connection with Georgia Tech Research Institute Agricultural Technology Research Program with the long-term vision to use sensor data and machine learning to generate animal welfare insights.

As consumers are becoming more concerned about how animals are raised as a food source and food service providers, e.g., McDonald, Kroger, Tyson Food, etc., feel the pressure to ensure ethical treatment of the animal during its lifetime, AudioT's vision is to help establish Key Welfare Indicators (KWIs), industry best practices, and provide new and improved ways to monitor key performance indicators (KPIs) through the extraction and analysis of bird behavioral data.

Audio and video data of chickens, especially bird vocalization data, has been the core input of AudioT's welfare classification and monitoring models and allow for deeper insights into bird behavior, health, and living conditions.

Objectives

Though machine learning and AI are often the first things that come to mind when analytics is mentioned, effective visualization of insights and data is a science and art of its own. This project seeks to begin exploring compelling methods of communicating AudioT's novel approach of monitoring animal welfare using analytics techniques applied to auditory signal data. While the innovative work done by AudioT's machine learning teams have and would certainly impress analytics focused audiences, visualizations of the outputs were requested to extend the reach to a wider and more diverse audience.

More specifically, while AudioT's machine learning teams focus on developing and building out classifiers to decode the vocalizations of chickens, this project specifically revolves around meeting stakeholders' needs for monitoring animal welfare metrics and comparing the quality between the different zones, houses, and flocks within, or even between, farms.

Therefore, the purpose of the AudioT's visualization project is to create an interactive data dashboard that can be used by the live operations teams of poultry farms to monitor and manage animal welfare in near real-time, and poultry integrators and retail food service providers to gain assurances that poultry suppliers are adhering to animal welfare guidelines.

Business Cases and Benefits

If successful, this project will establish the foundations of a dashboard that will offer benefits to multiple stakeholders. The dashboard will allow AudioT to highlight and demonstrate the value of utilizing audio data to monitor and manage live operations (KPIs) and animal welfare (KWIs) in a way that has not been done before. Both the live operations and animal welfare focused user bases will directly benefit by having access to sensor and controller generated telemetry data as well as higher level insights providing actionable temporal and spatial comparisons. Using this information, the intention is to allow the industry to make and show improvements in animal welfare standards as well as operational efficiency.

Project Overview

Specifically, the set of deliverables will include the identification of several KWIs based on discussions with the project sponsor. This is necessary as there does not yet exist a standardized set of KWIs across the industry. A Python script that will process the raw data from a wide and flat (denormalized) format to a normalized relational format will also be developed. Finally, the core output will be the deployment of one or more interactive, non-public dashboard(s) developed in Tableau.

Project Scope and Deliverables

The project aims at the implementation of KWIs in the form of visualizations. This involves the creation of scripts to transform and/or pre-process raw data into final analysis dataset(s) and the deployment of one or more interactive, non-public dashboard(s) developed in Tableau.

It was decided to bound the scope of this project by leaving the deployment of any databases or other IT infrastructure as out-of-scope. User level security and access controls were also left as future development items. Additionally, more complex predictive modeling and risk-adjusted benchmarking could not be implemented due to time and data resource constraints but were left on the future development agenda as well.

Project Risks

Some of the most significant hurdles that had to be overcome for the success of the project included the limited availability of data while prototyping. During the initial prototyping phase, only synthetic data, that was loosely based on real world observations, were available for exploratory analysis. Each iteration, when new synthetic data became available, the visualizations had to be updated and on occasion it became apparent that certain elements of the visualizations became unsuitable, unstable, or were insufficient for the new data sets. Over several iterations, however, the visualizations did stabilize, and fewer updates were required. This provided some confidence that the dashboard would eventually be able to project live data effectively.

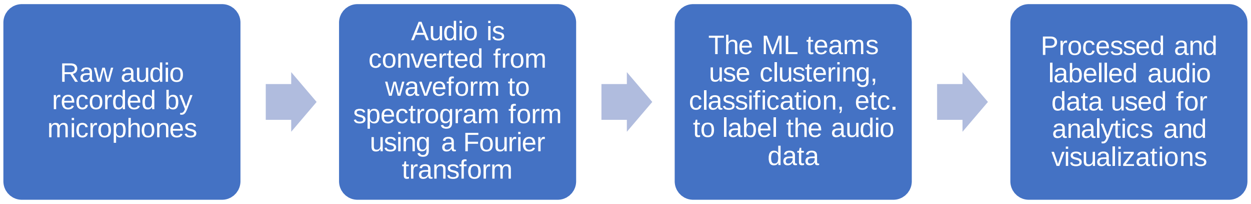
Another set of technical challenges stemmed from the limitations of Tableau. Certain features of Tableau were inaccessible due to paywalls or just did not exist. Particularly, the processes of collaborating on and sharing formulas and visualizations were cumbersome.

Finally, with limited opportunities to receive feedback from the intended end users (farmers, animal welfare monitors, distributors, etc.) it was difficult to assess whether any path the dashboard had started to take was the right one. A rough initial prototype of the dashboard was presented to a select audience at the IPWA Poultry Sustainability and Welfare Summit where the work up until that point did receive some positive feedback. The dashboard is still early in its development process and there is still uncertainty around whether any significant pivots will be required in the future to elicit significant adoption from the industry, but regardless, valuable lessons were learned that could inform future designs.

Data Properties

Audio Data

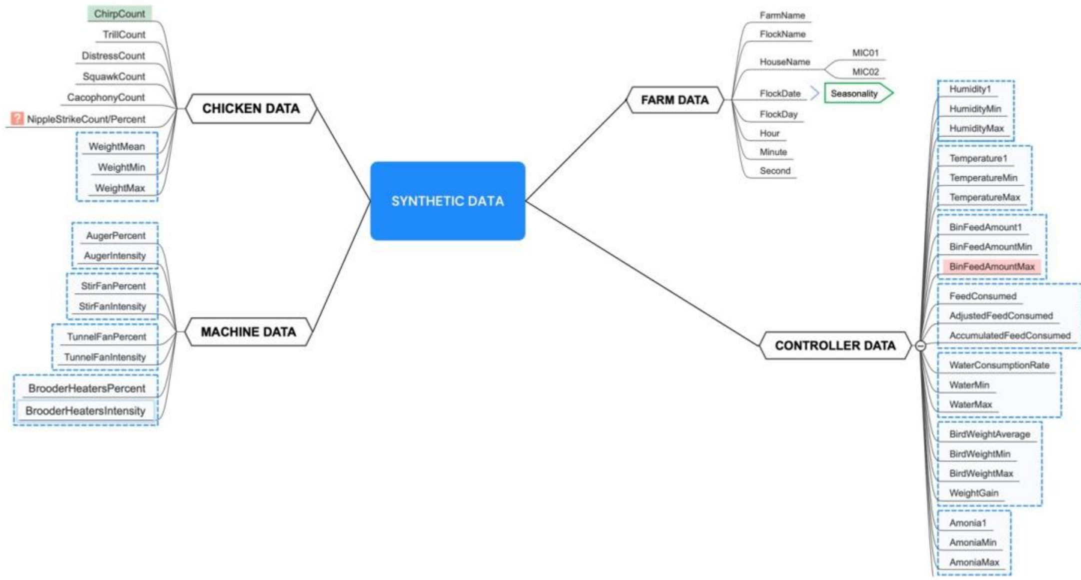
As mentioned, audio data has been the core input of AudioT's welfare machine learning and analytics that enables the understanding of bird behavior, health, and living conditions. Bird audio data such as chirps, distress expressions, and nipple strike sounds are considered the leading indicators of the flock distress and welfare level and become a part of this project's focus. Below is a flowchart that briefly lays out how raw audio signal data from the microphones located within the houses is turned into various predicted values, such as bird weight, that feed the dashboard.



Dataset

The data that feeds the dashboard can be divided into 4 main groups: farm, controller, machine, and chicken data. Farm data consists of descriptive information about the farm, such as the farm, flock, and house names, as well as the date/time dimension in day, hour, minute format. The controller data is comprised of features that describe the general conditions experienced by the chickens measured by various sensors distributed throughout a house. These include temperature, humidity, feed amount, total water consumption, and ammonia levels among others. Machine data complements the controller data in assessing the general living conditions experienced by the flocks and it describes the state of various machines found within a house. For example, machine data includes auger, stir fan, and tunnel fan noise levels in addition to the state of machines such as the brooder heaters. Finally, the chicken data revolves around the state and actions of the birds themselves, usually ascertained through their vocalizations captured by microphones placed at fixed intervals. Some examples of chicken data include bird weight (predicted based on vocalizations), chirp count (a proxy for activity level), and audio of nipple strikes (a proxy for amount of water consumed).

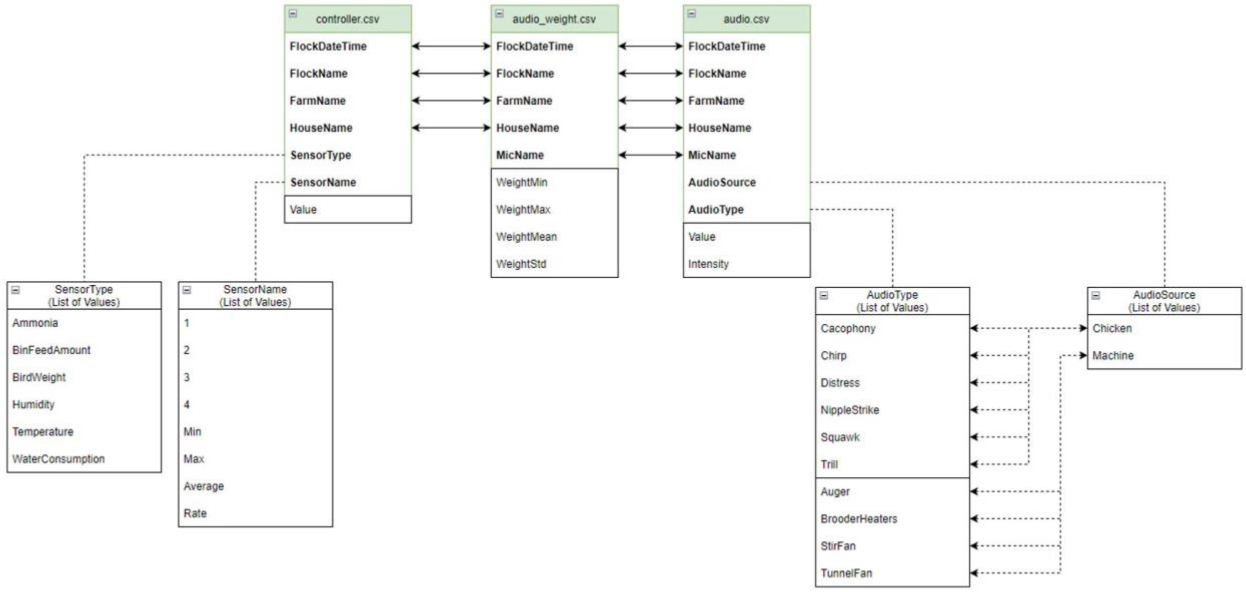
Data	**Description**	**Levels of Breakdown**
Farm data	Descriptive information about the farm, flock, house, and the date/time indicators (day, hour, minute)	• Multiple flocks • Flock • House • Zone • Microphone
Chicken data	Bird weight and vocalization (audio) data, e.g., counts of chirps, nipple strikes, etc., measured using several microphones placed at distinct locations.	• Multiple flocks • Flock • House • Zone • Microphone
Controller data	Data on the living conditions of the flock, including the temperature, humidity, fed amount, water consumption, ammonia level, etc., some of which are measured using sensors placed at various locations of the house.	• Multiple flocks • Flock • House • Sensor number
Machine data	Data on the machine operations, e.g., auger, stir fan, tunnel fan, brooder heaters, etc., that complements the controller data in giving insights into the living conditions of the flocks.	• Multiple flocks • Flock • House • Zone • Machine number



Data Engineering

The raw data for this project were provided by AudioT in a wide format that contained variable values embedded into different columns. In other words, data for audio captured by different microphones were contained in multiple columns, one for each microphone (e.g., MIC01_Chirps, MIC02_Chirps, etc.). Although this format can be useful in the development of statistical models where multiple predictors should ideally be on the same row-level record as the associated outcome, the wide format is not ideal for data visualization purposes.

In order to help facilitate data visualization development, the raw data files were melted into a long-form, dimensional layout, i.e., star schema. Multiple iterations were necessary to arrive at the final data model, which was determined necessary throughout the course of the project based on feedback collected from AudioT. An example of one of the dimensional data models used in this project are presented in the diagram below.



Another significant challenge encountered during the project was the data interval frequency. The original raw data files were based on equipment sensor data that was polled every minute. Due to the high number of combinations and cardinality from the numerous sensors, flocks, poultry houses, and other dimensional data, the transformation of wide data to its long-form equivalent, at a minute-by-minute level, resulted in datasets that were extremely large, at least for the purposes of data visualization using tools like Tableau. For example, data for a just couple of flocks and houses for a couple of months resulted in analysis datasets totaling multiple millions of records in data files that were 3-5 gigabytes in total.

To ameliorate the data-volume related challenges with this project, data transformation techniques were further applied to resample minutely data into larger units of time. Initial efforts resampled data into daily intervals, which was determined to be too large for meaningful anomaly detection. In the end, the most useful format was a dataset that was sampled at every hour, resulting in a workable balance between granularity and file size.

All data transformations were applied using the pandas Python package using Jupyter notebooks, which helped to greatly simplify the sharing of data transformations between the 3 team members.

Dashboard Design

Based on initial requirements, several data visualization approaches were explored. Each team member worked on different dashboard design approaches that enable a variety of flock welfare data use cases, from a novel, all-in-one visual, to a zone-level day-to-day monitoring, to flock multi-level comparisons. Below is a deep dive into the individual approaches.

Approach 1: Core Metrics-Combined Visualizations

Two recurring themes during those initial discussions were the importance of monitoring temperature and humidity and their impact on chicken behavior and well-being as well as the importance of chicken weight uniformity. Scatter plots overlaid with box and whisker plots were developed to efficiently convey these key metrics.

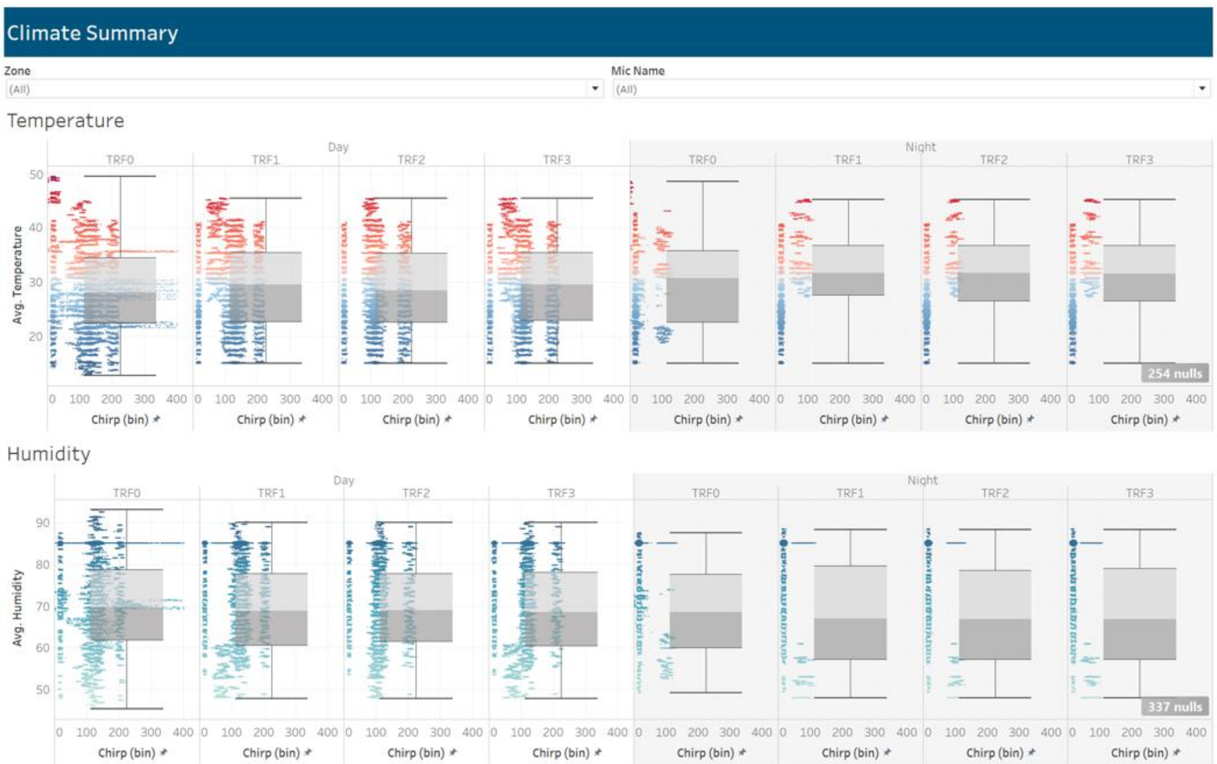


Figure 1. Climate Data Summarized

Figure 2. Chicken Weight Data Summarized

A time element was added by aggregating the minute/hour based raw data into daily/weekly data and allowing the user to scan through the aggregate plots by day or week (or in some cases, in even finer detail).

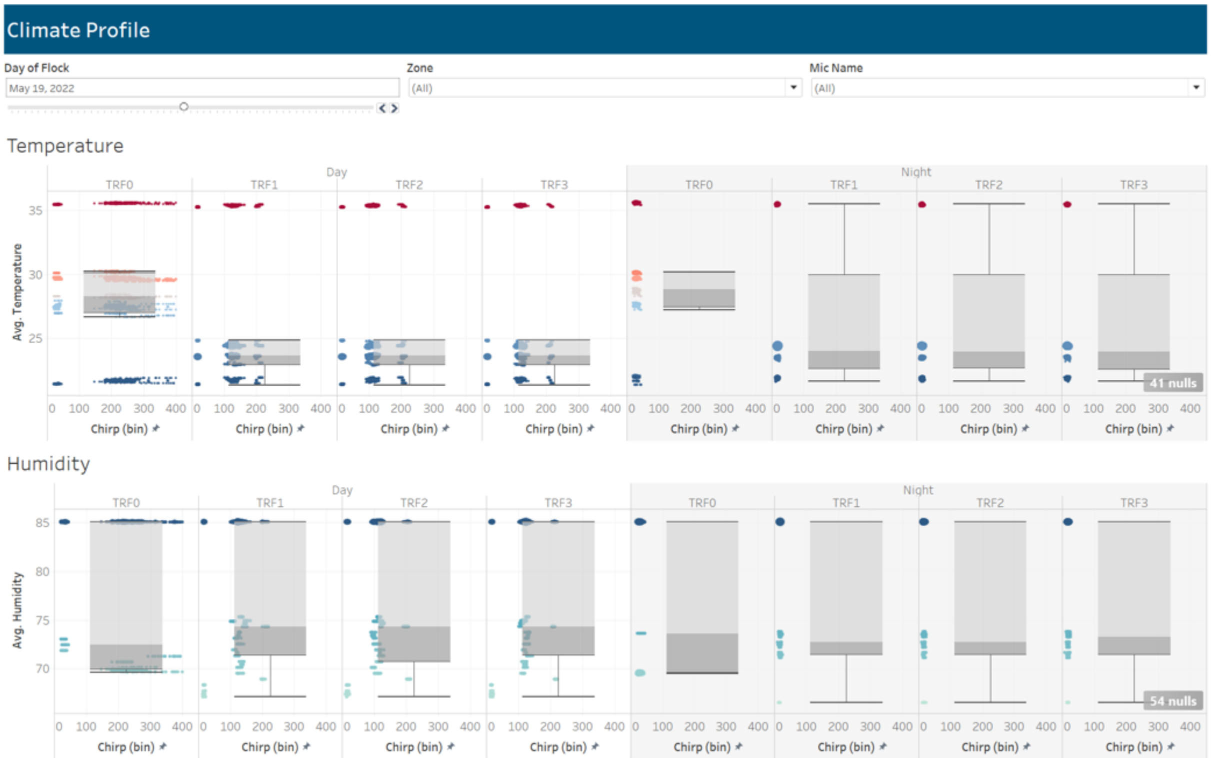


Figure 3. Climate Data with Time Element

Figure 4. Weight Data with Time Element

The box and whisker plots, of course, were useful in addressing the need for ranges, averages, and variances to be easily ascertained. This was in direct response to the need for a visualization that could quickly convey information on chicken weight uniformity across microphone zones, houses, and flocks. They were also applied to the climate plots, amongst others, because of their effectiveness. The use of scatter plots in combination with the box plots allowed for an additional dimension to be displayed within the same plot. For instance, the chicken weight box plot was overlaid on top of a scatter plot of chicken weight (audio based) against number of chirps (a proxy for the activity level of the chickens). This allowed information on the relationship between chicken weight and activity level over time to be shown concurrently with the statistics previously mentioned.

A more experimental method of data summarization and presentation was explored to tie together several of the core metrics and convey the auditory nature of AutioT's unique and novel value proposition in an effort to give a hypothetical user a quick synopsis of overall conditions at a glance. This method involved creating bins for both the chicken weight data, which is the output of an audio-based prediction model, and the chirp count data.

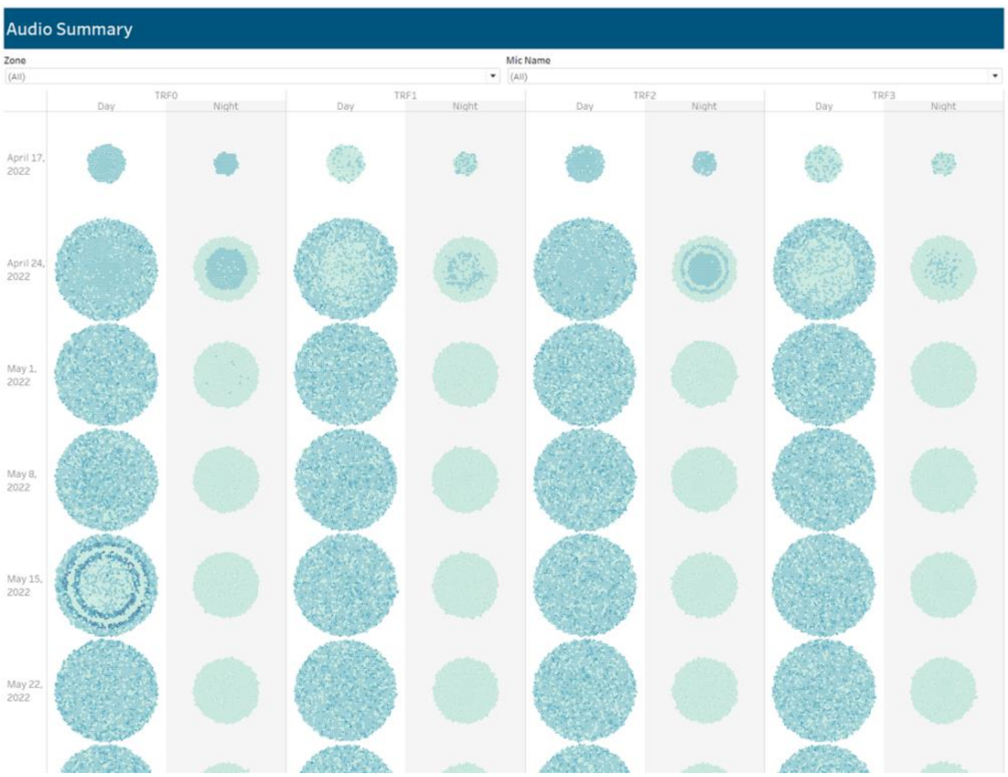


Figure 5. Audio Data Summarized

The bin sizes were determined based on the data provided, mainly through trial and error, and were fine-tuned as the stochastic data was replaced with more lifelike observations. Prior, real-world knowledge also influenced the choice of bin sizes. For instance, a bin size of less than one was determined to be inappropriate for the number of chirps as this would represent a fraction of a chirp, not something that would be useful to the end user. The unique intersections of each group of bins were then used to form a bubble chart. The size of each bubble was then determined by the number of chickens that fell into the newly combined bins. The position of each bubble within the plot was determined by the estimated weight of the chickens by sorting them in ascending order. In other words, the bubbles pertaining to lower chicken weight bins were found closer to the centers of the plots, and the bubbles pertaining to the higher chicken weight bins were found closer to the edges of their respective plots. Finally, the color of each of the bubbles was determined by the value of the chirp count bin that it belonged to. The colors were divided into five discrete shades of blue. The higher the chirp count, the more intense the color, and vice versa, the lower the chirp count, the fainter. Five discrete shades of the same color (in this case, blue) were used for several reasons. Beyond five colors, or using a continuous color scale, the minute changes from one group or type of chicken to the next becomes nearly imperceptible. One of the main use cases for this experiment was to allow certain anomalies to be immediately identifiable, therefore it was imperative that they stood out visually. In addition, using distinct shades of the same color allows for certain color-blind users to tell them apart more easily, making the tool accessible to a wider user base.

Figure 6. Audio Data with Time Element

Following the theme of giving the user various levels of granularity with which to observe the data, this plot was aggregated at the week level and the user was given the ability to flip through the weeks and to compare one week with another.

Approach 2: Zone-Level Monitoring

The purpose of this dashboard is to provide live operations teams with a tool that can help detect anomalous trends and patterns in one or more poultry houses. The tool provides users with hour-by-hour visibility into audio- and environmentally derived data using sensors placed throughout a poultry house. Data that falls outside of user-defined standard deviation limits are prominently displayed, so that operations teams can a) quickly see if the flock is exhibiting undesirable behaviors, and b) quickly correlate environmental factors, such as nearby machine noise and temperature, to the anomalous events.

For example, an unexpected spike in flock chirp and/or distress vocalizations picked up by one of the microphones may be coinciding with a corresponding spike in the noise levels generated by a nearby feed auger.

The dashboard is designed to mimic, to the extent possible, the physical layout of the poultry houses being operated by AudioT at the time of this project. During the course of this project, AudioT provided the following model of a typical poultry house.

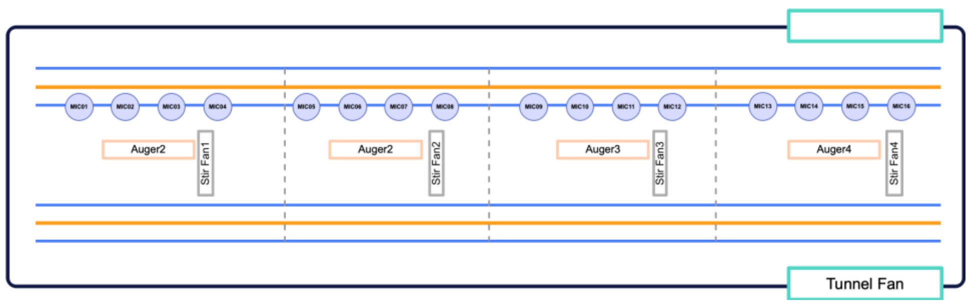


Figure 7. Poultry House Layout

In the figure, the poultry house is divided into four major zones that each have a feed auger and stir fan. These zones are further subdivided into 4 microphones, each of which collect audio data from the flock to be used in proprietary algorithms that can detect the type and frequency of bird vocalizations.

It is important for operators to understand where anomalies may be occurring, so the key design goal of this particular dashboard was to explore effective ways to concisely display many microphones in the context of their physical locations.

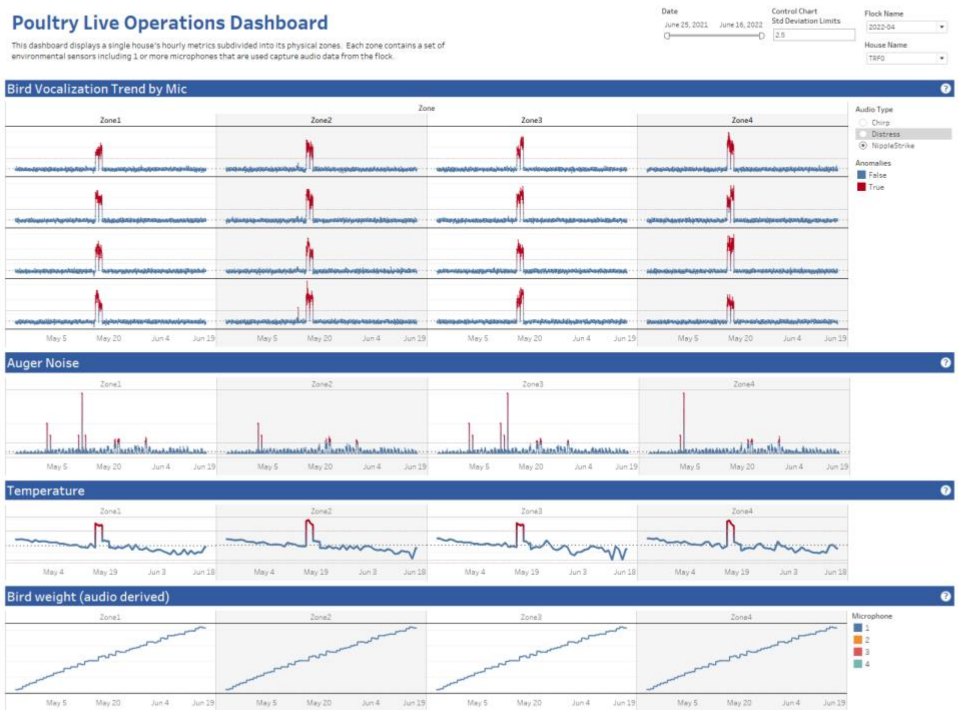


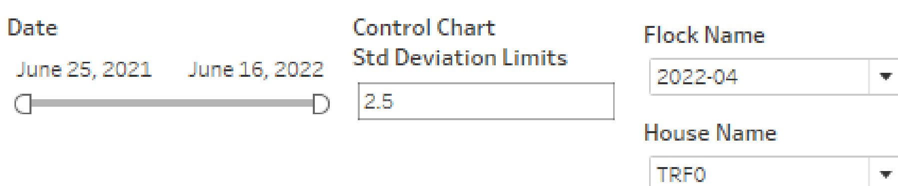
Figure 8. Poultry Live Operations Dashboard Overview

The Poultry Live Operations Dashboard is organized into four columns, each representing one of the four major zones in the Poultry House Layout diagram. Each of the zones contain four metrics divided into their own rows, each of which are metrics derived from various audio- and environmentally derived data. These metrics, which are individually discussed in following sections, include:

1. Bird Vocalizations
2. Auger Noise
3. Temperature
4. Bird Weight

Global Features

The dashboard contains four user-configurable parameters that apply globally to every visualization.



Flock and House Selector

The *Flock Name* and *House Name* dropdown menus allows the user to select specific flocks and poultry houses for display.

Date Selector

The *Date Selector* slider allows users to set the start and end point of the dashboard's visualizations, which can help to drill down into days in which an anomaly was detected in order to conduct deeper analyses, or to zoom out to gain an overall understanding of the current selected flock's status.

Control Chart Std Deviation Limits

The numerical input box allows users to set a custom standard deviation threshold to be used in the dashboard's control charts. By default, it is set to +/- 2.5 standard deviations from the mean, but users may choose to adjust this value based on their specific needs.

Bird Vocalization Trend by Microphone

The first section of the dashboard displays bird vocalization data captured by each of the four microphones located in each zone.

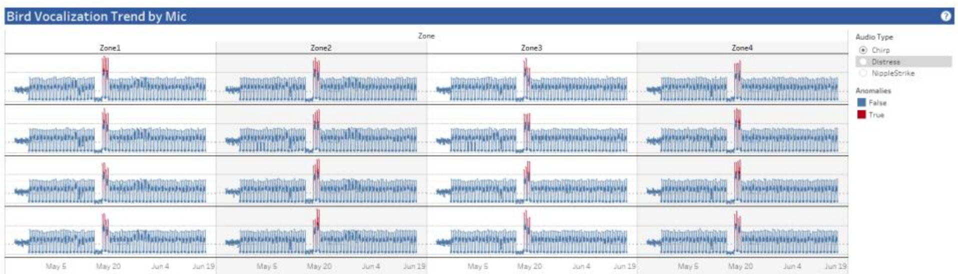


Figure 9. Bird Vocalizations by Mic Section

The *Audio Type* radio button selector allows users to change the visualization to display the frequency of bird vocalizations according to their type, including chirps, distress, and nipple strikes (i.e., pecking on water lines).

In the figure above, it can be observed that the selected flock experienced an anomalous event in the frequency of chirps on or around May 20. A lull in the number of chirps was initially observed, and then a following large spike (represented in dark red as an anomalous frequency exceeding the default 2.5 standard deviations), and then a return to normal shortly thereafter.

Auger Noise

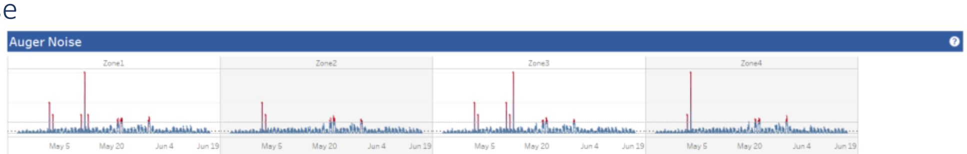


Figure 10. Auger Noise Section

The second section displays noise levels associated with each of the four augers inside each poultry house. In the example above, it can be observed that there were brief, large spikes in noise levels, which may warrant further investigation.

Temperature

Figure 11. Temperature Section

The third section displays the poultry houses temperature according to thermometers located in each major zone. The same anomaly detection method is utilized, which is a user-configured standard deviation threshold from the mean. Here, it can be observed that there was an anomalous temperature spike on or around May 20, which is the same pattern that we observed in the bird vocalization anomaly around the same date.

Bird Weight

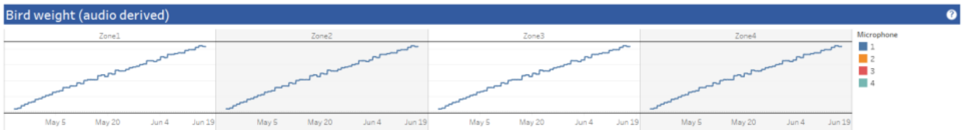


Figure 12. Bird Weight Section

The final section displays the predicted bird weight by zone and microphone. This section was added based on user-feedback, so that deviations from expected weight gain can be correlated with anomalous events in the vocalization and environmental sensor data. As previously discussed in this report, the equal distribution of bird weight across a flock and house were important outcomes, so individual lines to show each of the four mics in each zone were implemented. However, the synthetic data used in this project did not have any variation in this metric, so for purposes of this example, the four series are all on top of each other. However, in a real implementation, the predicted weight gain trends at the mic level would be visible here, so that large deviations can be identified and further investigated.

Approach 3: Flock Multi-Level Drilldowns

This approach allows users to drill down to different levels of the multi-flock data and pinpoint exactly to which segment of the flock that the abnormal behaviors and conditions occur. There are several levels of the data explored in this approach, described in Figure 13: Multiple flocks → Individual flock → House → Zone → Microphone location.

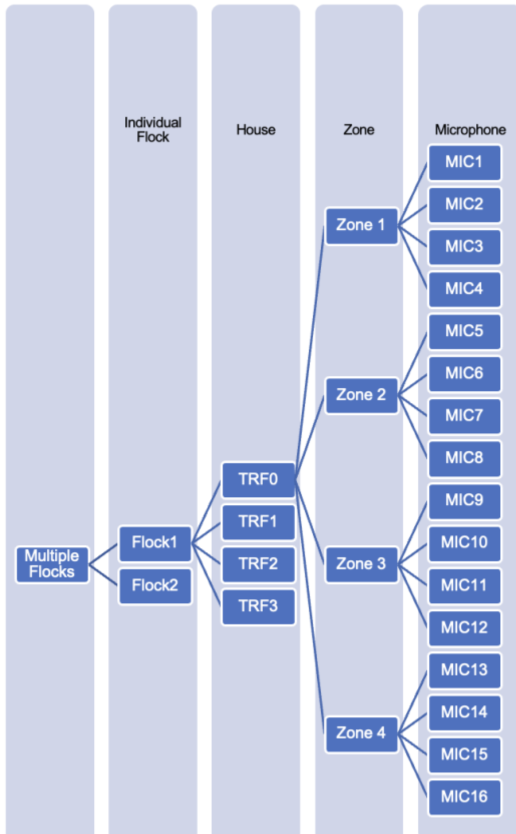


Figure 13. Multi-level flock data structure

In this approach, user can start off by comparing the flocks on the "All Flocks Welfare: Flock Comparisons" tab, then drill down to the next level "Flock Welfare: House/Mic Comparisons" where they can compare the houses or microphone data within a specific flock, and finally investigate the controller and machine intensity anomalies in the specific house using "House Welfare" tabs. This design is enabled by the story feature in Tableau, essentially a sequence of four transitional dashboards, to convey a data story or narrative about poultry welfare (Figure 14).

Figure 14. Multi-level drilldown menu

Flock Comparisons

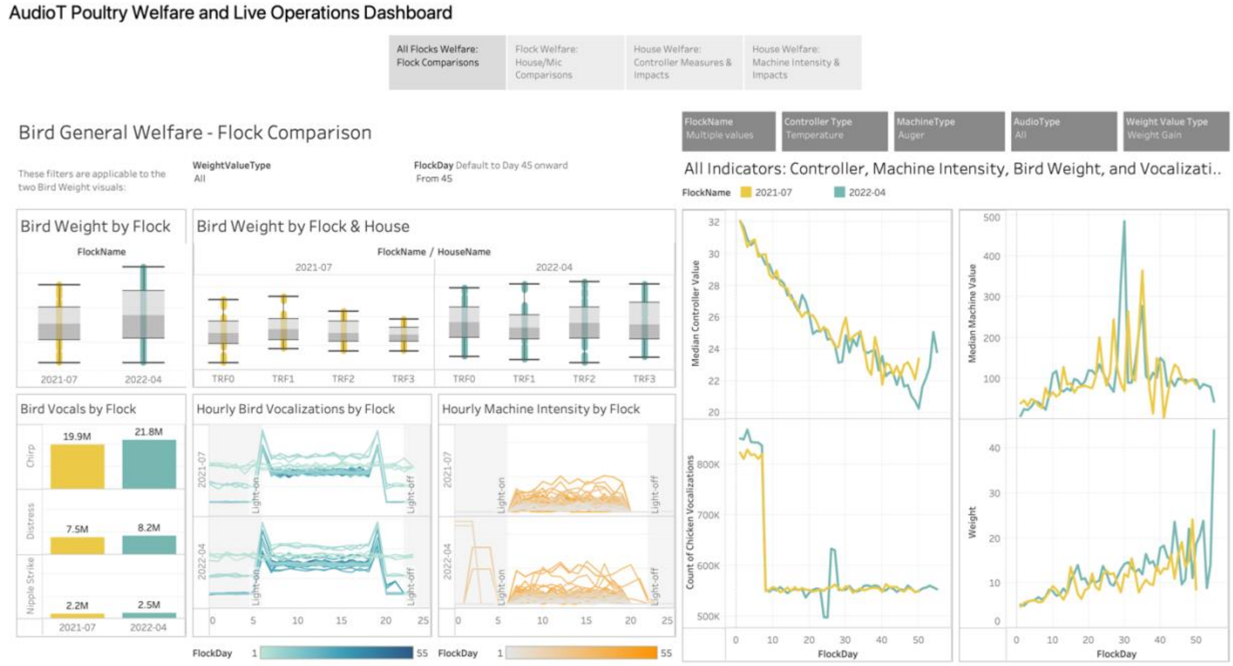


Figure 15. "All Flocks Welfare: Flock Comparisons" Tab

Flock comparison is the highest level of comparison where users can select two or more flocks to compare the flock outcomes and well-being. The multi-flock comparison is useful when users have identified a gold standard flock that produces quality birds in the best conditions and want to compare a new flock with this baseline to understand the gaps.

Regarding dashboard design, box and whiskers plots are useful to visualize the weight uniformity between the flocks, while line graphs allow for comparing the progress over time of different flocks. A bar chart is employed to compare the aggregate bird vocals between the flocks. In addition, the consistent use of color helps users quickly recognize and separate the flocks across all visuals.

Flock comparisons are visualized for the following metrics and purposes.

Metric view	**Purpose**
Bird weight, default to flock day 45 to the end of the flock cycle	To detect non-uniformity in weight, especially the weight output when the flock reaches maturity
Bird vocals, including chip, distress, nipple strike	To evaluate the level of distress caused by the living conditions
Hourly bird vocals	To monitor sleep & rest and level of distress during light-off hours
Hourly machine intensity	To monitor sleep & rest and machine noise level during light-off hours
All indicators over time, including controller, machine intensity, bird weight, and bird vocals	To track how the indicators progress over time by flock

The global filters allow more flexible comparisons as users can switch between the flocks and select the type of controller data, machine intensity, bird vocals, and weight values (bird weight vs. weight gain) from the dropdown lists.

Figure 16. "All Flocks Welfare: Flock Comparisons" Global Filters

As users identify the need to explore a flock from the comparisons, they will proceed to the next level which is on the "Flock Welfare: House/Microphone Comparisons" tab.

House/Microphone Comparisons

A key feature of this tab is the ability to select the level of comparisons within a specific flock. As described in Figure 13, House, Zone, and Microphone are the next levels of the data after the flock; however, we can overlook the Zone level because a) another design approach already tackles at this level, and b) Zone data is only available to a few but not all indicators. An input from the stakeholders suggests that being alert at the Microphone level is more valuable than the Zone level as it reduces the investigation scope when anomalies occur, while comparing the houses gives them a more high level of the flock overall well-being. Therefore, House and Microphone are the two available drilldown options on this tab and can be selected from the *FlockDrilldownLevel* dropdown list. Figures 17 and 18 show how the dashboard embraces different values of the *FlockDrilldownLevel* global filter and corresponds to the comparison level of choice.

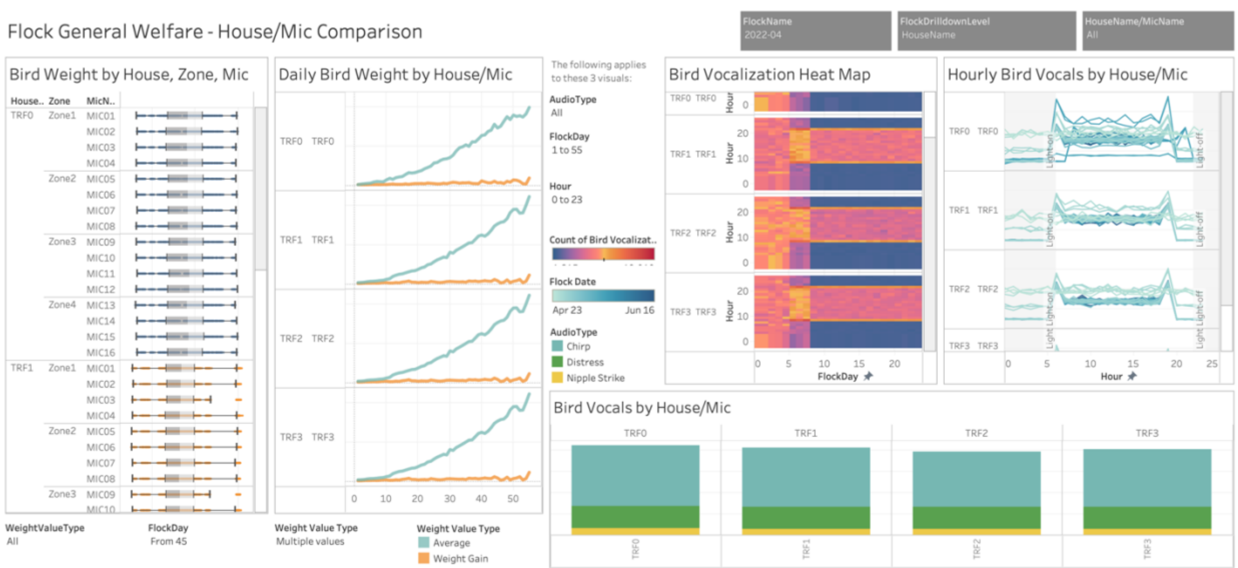


Figure 17. House Comparisons

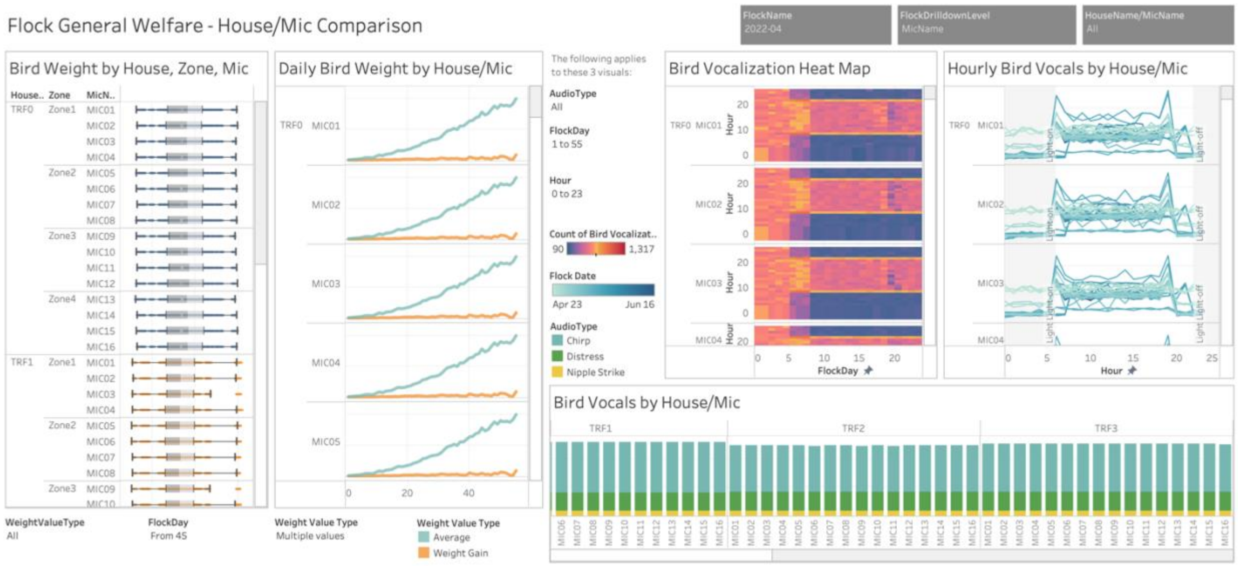


Figure 18. Microphone Comparisons

Regarding dashboard design, the box and whisker plot is the go-to for comparing the weight distributions and uniformity between houses and microphones. Line charts are employed to show the progress over time of indicators such as bird weight or bird vocals. A heat map with the multi-tone color scheme is useful for quick anomaly detection on the bird vocals and distress level. Finally, the stacked bar chart allows for comparing the aggregate bird vocals of different houses and microphones.

A drilldown feature is enabled in Tableau via the creation of a custom parameter, *FlockDrilldownLevel*, with *HouseName* and *MicName* field names being the two possible values, and a calculated field, *HouseName/MicName*, which is essentially a conditional clause that returns the possible values of the field name selected in *FlockDrilldownLevel.* Figure 19 shows the *HouseName/MicName* dropdown selections being the dependency of the *FlockDrilldownLevel* following the described setup.

House filter **Microphone filter**

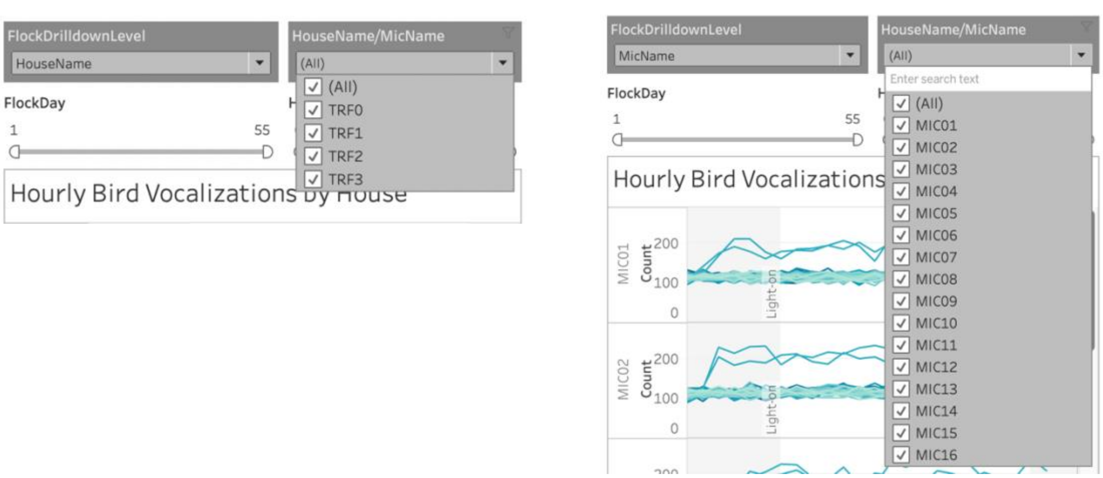


Figure 19. House/Microphone filters dependent on the selected value of FlockDrilldownLevel

Most visuals on this tab are similar to those on the “All Flocks Welfare” tabs at the granular scope. The addition of the Bird vocals heat map enables the anomaly detection functionality as users can quickly detect the hour of the day that the birds are more vocal than usual, which is a sign of distress possibly caused by the harsh living conditions. They will then proceed to investigate the controller or machine intensity to understand the causes of distress. House/Microphone comparisons are visualized for the following metrics and purposes.

Metric view	Purpose
Bird weight, default to flock day 45 to the end of the flock cycle	To detect non-uniformity in weight, especially the weight output when the flock reaches maturity
Daily bird weight	To track the bird weight and weight gain progress over time at house/microphone levels
Bird vocals, including chip, distress, nipple strike	To evaluate the level of distress caused by the living conditions
Bird vocal heat map	To detect anomalies in the bird vocals and the level of distress by hour of day
Hourly bird vocals	To monitor sleep & rest and level of distress during light-off hours

House Controller and Machine Intensity

The last two tabs, displayed in Figures 20 and 21, focus on the bird welfare at the scope of a flock house, providing that users have located the house where anomalous behaviors occur. The objective is to provide measures of the controller factors and machine intensity in a specific house, how they change over time, and how these changes reflect on the flock outcome indicators, including weight and vocalization. Again, line charts are employed to show the progress of controller data over time and the potential correlations between the indicators, and a heat map with three-tone color scheme is used for the anomaly detection purpose.

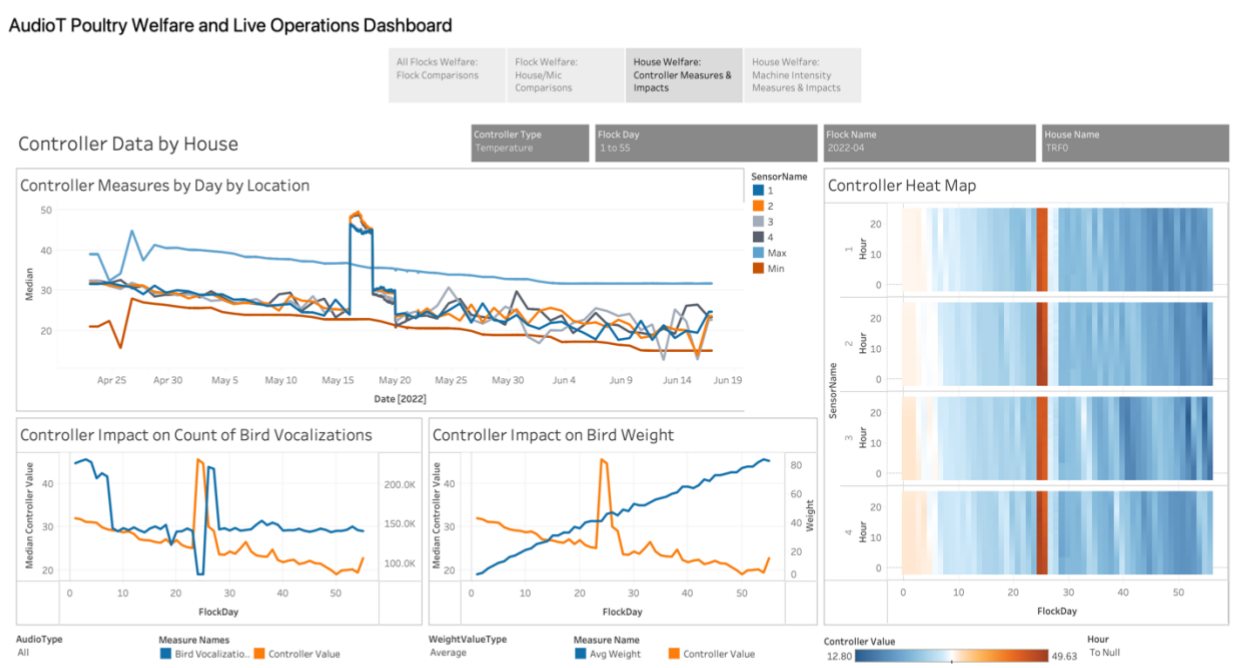


Figure 20. Controller Measures & Impacts tab

Figure 21. Machine Intensity Measures & Impacts tab

The tabs share similarities in the visual design and purposes. The global filters are also consistent between the tabs, which allow users to switch between the controller factors and machine types and specify the timeframe of analysis and the flock house (Figure 22).

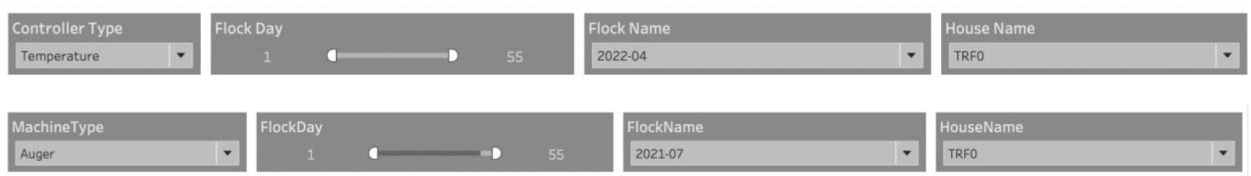


Figure 22. Controller and Machine Intensity Global Filters

The visuals of both tabs are described as followed.

Controller Visual	Machine Intensity Visual	Purpose
Controller Measures by day and sensor, with the controller factor selectable from the *ControllerType* global filter	(No counterpart visual)	To monitor and compare the progress of the controller factor by the individual sensor and detect anomalies if values are out of the bound created by the estimated maximum and minimum values.
(No counterpart visual)	Hourly Machine Intensity by day	To monitor sleep & rest and machine noise level during light-off hours of a specific house
Controller Impact on Bird Vocals, with the controller factor selectable from the *ControllerType* global filter and the bird vocal type	Machine Impact on Bird Vocals, with the machine type selectable from the *MachineType* global filter and	To monitor the aggregate (median or sum) progress of each controller factor and machine intensity over time and detect anomalies that potentially increase bird vocals. An

from the *BirdVocalizationType* filter	the bird vocal type from the *BirdVocalizationType* filter	extreme/abnormal value in controller and machine noises might signal a high distress level among the house.
Controller Impact on Bird Weight, with the controller factor selectable from the *ControllerType* global filter and the weight value type, e.g., bird weight or weight gain, from the *WeightValueType* filter	Machine Impact on Bird Weight, with the machine type selectable from the *MachineType* global filter and the weight value type, e.g., bird weight or weight gain, from the *WeightValueType* filter	To monitor the aggregate (median or sum) progress of each controller factor and machine intensity over time and detect anomalies that potentially cause bird weight loss. An extreme/abnormal value in controller and machine noises might disrupt the bird consumption of food and water, leading to weight loss.
Controller Heat Map	Machine Intensity Heat Map	To detect extreme values in the controller factors and machine noises by hour of day, broken down by the sensor number or machine number which pinpoints the exact location of extreme conditions.

Analysis and Interpretations

Although the data used in this project were synthetic and difficult to find correlations that would be meaningful in the real world, most dashboard design approaches still provide some context into how anomalous events may be more easily detected and correlated across different data points collected by AudioT.

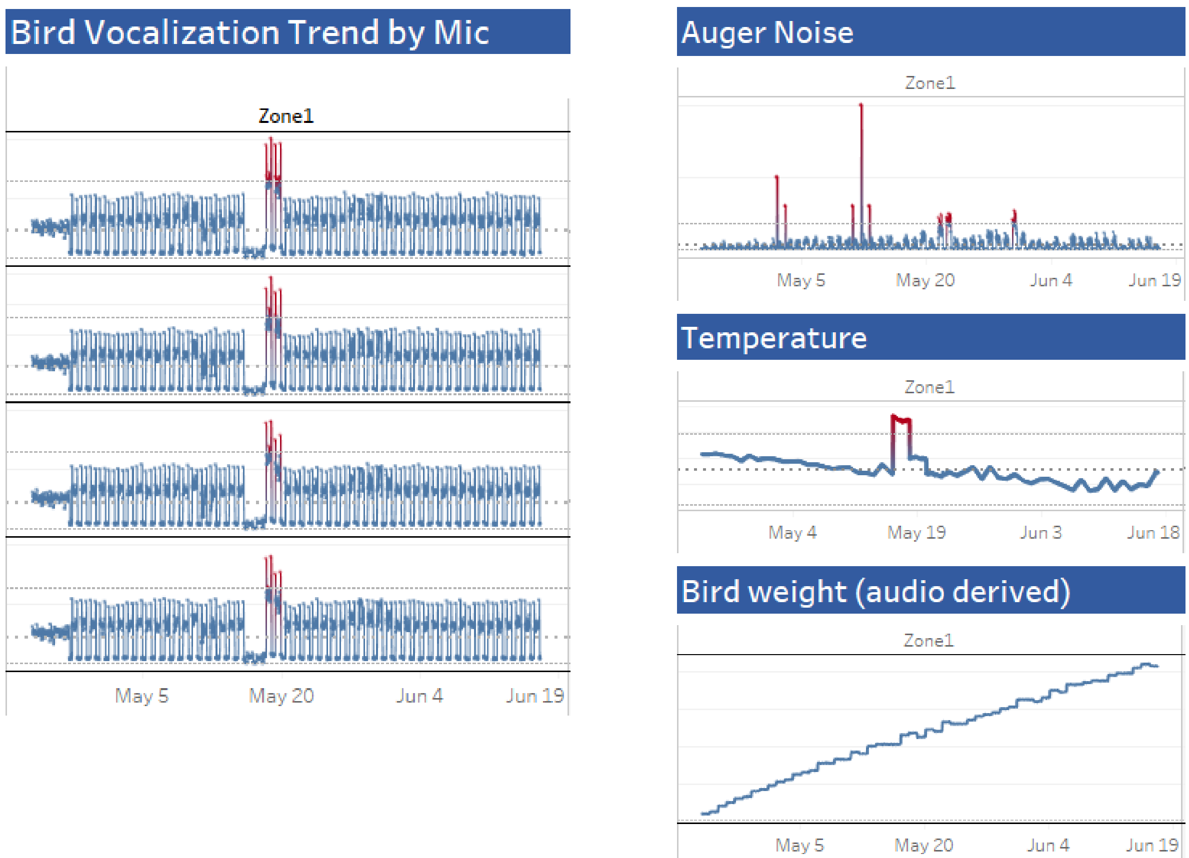


Figure 23. Anomalies detected in Zone1

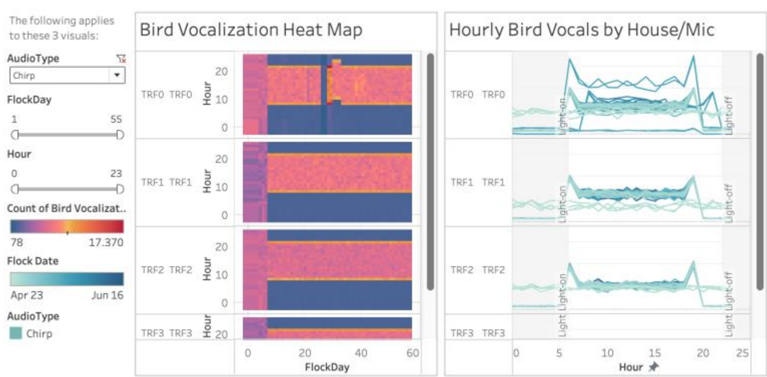
In the figure above captured in Approach 2: Zone-Level Monitoring, the preliminary finding is that there was an anomalous change in chirp behavior (discussed previously). The layout of the dashboard lends itself to quick comparison, and an immediate visual correlation can be found in the spike in temperatures that coincides with the period in which chirp counts dropped off significantly. The spike in temperatures lasted for approximately 24 hours before returning to normal levels. The spike in chirp levels occurs for a duration of approximately 24 hours after the temperature returns to normal.

Auger noise did not immediately appear to be correlated with these anomalies observed in chirp counts and temperatures. Further, there does not appear to have been any observable effect on bird weight as a result of these vents, as the flock continued to grow on the linear pattern observed until that point.

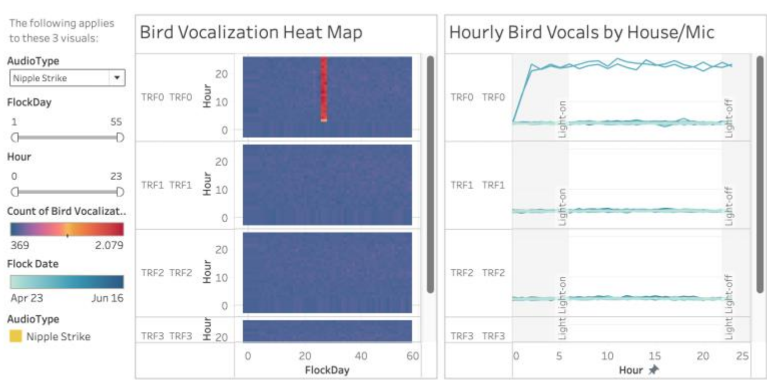
Similarly, anomalies can be detected using the visualizations in Approach 3: Flock Multi-Level Comparisons. In the House/Mic comparisons, the Bird Vocals Heat Map displays an abnormal pattern on flock days 24-27 for Flock 2022-04 House TRF0 that does not match with other houses' patterns. Birds are also more vocal for at least two days in this house as described in the Hourly Bird Vocals by House/Mic visual.

Figure 24. Abnormal pattern of bird vocals detected in House comparisons

Using the *AudioType* filter, we identify chirps and nipple strikes as the two audio types that appear to be abnormally high from the heat map. While the bird chirps increase on day 24-25, the birds start to nipple strike more often starting day 26, signaling the living conditions that become more extreme over this period. This calls for a deep dive into the controller factors and machine intensity to identify the source of distress.



a) Chirps



b) Nipple Strikes

Figure 25. Chirp and nipple strike increase on flock days 24-27

Looking at the “House Welfare: Controller Measures & Impacts” tab and multiple controller factors using the *ControllerType* filter, we identify temperature as a cause of the bird behaviors in Flock

2022-04 House TRF0. The temperature spike on day 24-25 across all sensors is captured in the line charts, and while this does not seem to affect the bird weight, it does correlate with an increase in the total bird vocals that occur 2 days later. The hottest day (flock day 24) is also reflected in the Controller Heat Map with the highest temperature going up to 45 degrees, which is 20 degrees higher than the average temperature in the house.

Figure 26. Controller anomaly detection

Similarly, we investigate the machine noises using the visualizations in the "House Welfare: Machine Intensity Measures & Impacts" tab. While other machines are consistently on, auger needs to be turned off during the resting hours to eliminate noises in the house. There are four occurrences that the auger is on between midnight and 5 am on flock days 10-11 and 19-20, and these anomalies show in all visuals. While the auger noises do not seem to affect the bird weight or increase the bird vocals immediately, the extended period of noises from flock days 10 to 20 resonates with the high temperature on flock days 24-25 to create a negative impact on the bird welfare and cause a spike in the bird vocals afterward.

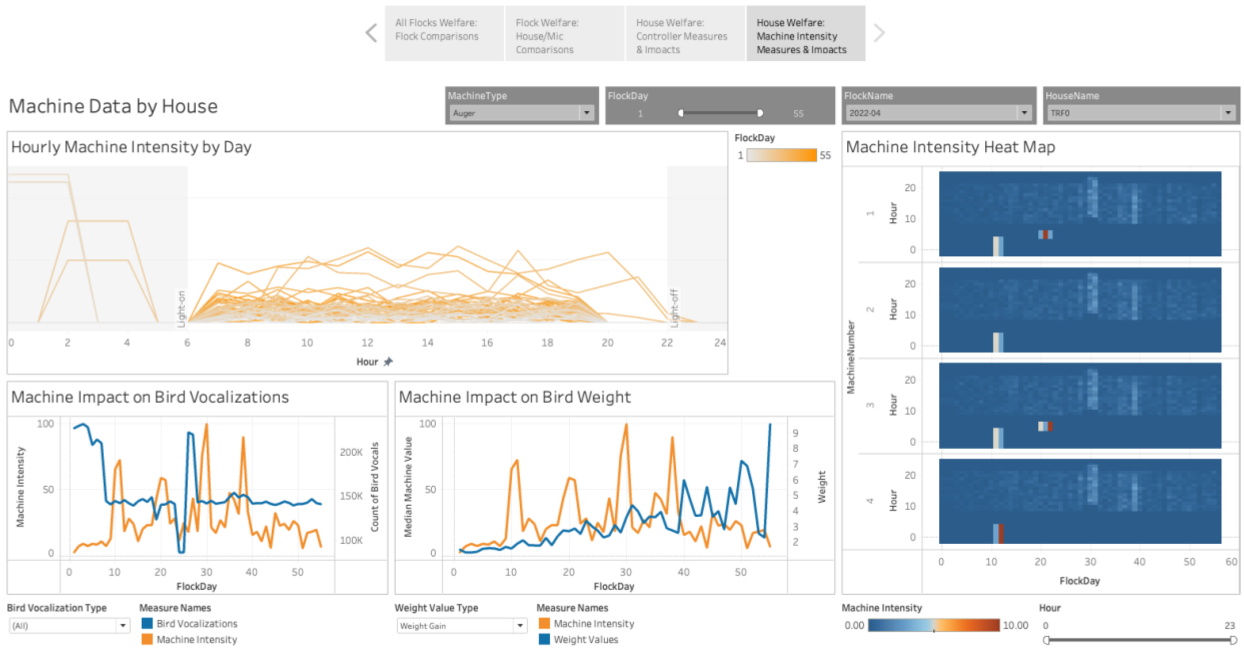


Figure 27. Machine noise anomaly detection

Conclusion and Next Steps

Without the granular telemetry data being collected by AudioT, it would have been difficult to identify these types of events that sometimes occur in a poultry house. Although it appears that the flock continued to grow without issue, it does not indicate that the temperature spike is something that could be ignored. The anomalous event could be a one-time event, but it also could indicate a major issue (or a future major issue) if they are not investigated further.

These initial designs were presented at the IPWA Poultry Sustainability and Welfare Summit where feedback was collected from potential users of AudioT's welfare dashboard. The feedback was applied in narrowing the project's focus down to the types of visualizations that resonated with the attendees the most.

For next steps, there are opportunities for data engineering work to keep the dashboards up-to-date and meet the stakeholders' need for a real-time bird welfare monitoring and analytics tool. This infrastructure work involves establishing a relational database for the streamlined data that feeds directly into the Tableau dashboards and automatically running the data pre-processing script to transform data into the appropriate schema prior to dashboarding.

Although more sophisticated animal welfare metrics that required further research and development using predictive analytics were not available at the time of this report, their inclusion into a dashboard using this type of layout would provide additional measures that live operations teams could use diagnose and troubleshoot potential issues related to business goals and animal welfare metrics. As the analytics demand for poultry welfare increases, novel visualizations other than the simple line graphs and bar charts can also be explored to better represent the KWIs data and provide AudioT with a competitive advantage against their industry rivals in terms of analytics capability.