Hamer Collision Model User Manual V.1.0

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Contents

Chapter 1

Getting Up and Running

1.1 Installation

1.1.1 Program Files

The model software package includes three files required for installation:

- **MCRInstaller.exe**: This is the Matlab Runtime Component required to run the model. It will only need to be installed once on each machine.
- **AvianCollisionModel.ctf**: This file is an archive of files that are part of the model application. It will be expanded into the appropriate directory structure the first time the model is run.
- **AvianCollisionModel.exe**: This is the actual model application. This is what is launched to run the model.

1.1.2 Installing the Matlab Runtine

The Matlab Runtime installs all of the components necessary to run applications developed using the Matlab computing environment. To install it, simply launch the **MCRInstaller.exe** application and follow the prompts.

1.1.3 Installing the Avian Collision Model

To install the model, two steps must be followed:

1. Create a directory to run the model from. It is suggested that
   `c:/Program Files/AvianCollisionModel`
   be used to make future upgrades easier.
2. Copy both **AvianCollisionModel.ctf** and **AvianCollisionModel.exe** into this directory.

1.2 Updating

When updates to the model become available, two steps must be followed to update the model installation:

1. Delete the contents of the model installation directory for created above.

2. Copy the new versions of **AvianCollisionModel.ctf** and **AvianCollisionModel.exe** into the empty directory

1.3 Launching the Application

To start the model application, double click on the **AvianCollisionModel.exe** file.

Chapter 2

Running the Avian Collision Model

2.1 Bird Characteristics

The avian collision model allows for the specification of the following bird specific parameters:

- Wingspan
- Length
- Mean speed
- Mean direction
- Mean flightpath height
- Variance of the flightpath height

The wingspan and length are species dependent, while the other parameters are determined from field survey data. The speed and direction parameters both assume a uni-modal distribution. This is clearly not true when the birds are, for example, coming inland in the evening and are seabound at dawn, resulting in a bi-modal distribution. In this case, different estimates should be produced for each mode. Flightpath height further assumes that the distribution in normally distributed (gaussian) in order to model the distribution of height using the variance statistic alone. The flightpath distribution in the horizontal axis is assumed to be uniformly distributed, meaning that flightpaths in the horizontal plane are all equally likely.

2.2 Wind Characteristics

The avian collision model allows for the specification of the following wind specific parameters:

- Mean speed
- Mean direction

The wind speed and direction are used in conjunction with the bird speed and direction to calculate both the orientation of the turbines relative to the flightpath and the orientation of the bird relative to the turbine as it passes through the turbine plane. Again, the distribution of these two parameters are assumed to be uni-modal. If this is not a reasonable assumption, then multiple runs of the model may need to be performed or the model updated to account for different statistical distributions.

If the **Enable** checkbox is disabled, than it is assumed that no wind data is available for the site. It is further assumed that the bird is flying downwind.

2.3 Survey Characteristics

The avian collision model allows for the specification of the following survey specific parameters:

- Horizontal radar range
- Passage rate

The horizontal radar range is required to determine the proportion of the measured passage rate that will pass through the wind farm. If, for example, the recorded passage rate is 10 birds per day, but the horizontal span of the wind farm perpendicular to the flightpath is half of the horizontal radar range, than the effective passage rate will be 5 birds per day.

2.4 Turbine Characteristics

The avian collision model allows for the specification of the following turbine specific parameters:

- Number of rotors
- Radius of the turbine
- Radius of the nacelle
- Angular velocity
- Maximum rotor chord length

These characteristics are typically all available from the turbine manufacturer. Since the formulas describing the exact shape of the turbine blade is often proprietary, a general formula was adapted from [1] which is based off of the maximum rotor length of blade. This specification is often available from the manufacturer.

To make it easy to switch between common turbine types, there is a drop down menu which allows a selection from the following varieties:

- GE 1.5se
- Gamesa 80
- Vestas V80
- Vestas V90

After selecting any of these items, any of the turbine parameters can still be individually customized.

If the **Enable** checkbox is disabled, than the turbine is not included in the avian collision estimate. This is useful for estimating the collision rate due to the tower components alone.

2.5 Tower Characteristics

The avian collision model allows for the specification of the following tower specific parameters:

- Height
- Diameter at base

- Diameter at hub
- Largest diameter
- Height at largest diameter

The tower is assumed to be circular. Other tower configurations would require an update to the model. This may be useful, for example, in estimating collision rates with cell towers or other static structures (when the turbine component is disabled as described above).

2.6 Wind Farm Characteristics

The avian collision model allows for the specification of the following wind farm specific parameters:

- Number of rows
- Number of column
- Distance between rows
- Distance between columns

The wind farm layout is assumed to be in a grid formation. Other configurations will require an update to the model.

2.7 Model Selection

The avian collision model allows for the selection of the turbine collision model to use:

- Hamer
- Tucker
- Podolski

The Hamer model can account for cases where the bird is traveling neither upwind or downwind, resulting in a rotated turbine relative to the flight path. The Tucker model is the accepted standard in the field but assumes downwind or upwind flight paths. The Hamer and Tucker models provide nearly identical results when this assumption holds. The Podolski model uses a different analytical approach for calculating the turbine collision probabilities which, in my opinion, are not as rigorous or sound as the Hamer or Tucker models.

2.8 Show Single Turbine Probabilities

When this checkbox is checked, only the turbine collision probability calculation is performed, and none of the wind farm calculations. This can speed up the process when comparing the 3 model types for a set of model inputs.

Chapter 3

Model Output

Currently, the model produces a number of figures in addition to the final collision rate estimate. These figures are helpful both in interpreting and validating the results. Furthermore, they may be used for inclusion in reports making use of the model. Following is a description of each figure type along with the calculation(s) it represents.

3.1 Turbine Collision

Figure 3.1 displays the result of the individual turbine collision calculations. The color scale at each point indicates the probability of collision with a bird flying in a straight path whose nose intersects the plane of the rotating turbine at that point. A value of 0 indicates no chance of collision (for example, all of the areas outside the radius of the turbine), and a value of 1 indicates a 100% chance of collision (for example, the center of the turbine where the stationary nacelle is). The figure shows the turbine from the perspective of the bird, so it may be rotated, resulting in an oval rather than a circle.

The mean collision probability displayed in the figure title indicates the mean collision probability across the surface of the turbine as seen by the bird. The mean rotation adjusted collision probability indicates the mean collision probability across the surface of the turbine, accounting for any rotation of the turbine (this is the value used in the collision rate estimates). For downwind flight (dead-on), these two values are identical. As the rotation of the turbine increases, so does the mean collision probability across its surface, since the bird will spend more time in the turbine rotor plane. Since the profile of the turbine is reduced, however the rotation adjusted collision rate does not necessarily increase.

3.2 Wind Farm Layout

Figure 3.2 shows the layout of the specified wind farm against a generic background image. It indicates both the spatial dimensions, as well as the relative rotor size and orientation.

3.3 Compass and Directions

Figure 3.3 displays the relevant directions included in the collision estimate: the bird flight path, the wind direction, and the bird's orientation. When the wind direction is non-zero and different than the flight path direction, the bird will have an orientation that is rotated from its actual flight path. For example, if the bird is pointed north, but there is a wind blowing to the west, the flight path with be north-west.

3.4 Wind Farm Collision Probabilities

Figure 3.4 shows the wind farm, from the perspective of the bird, and the associated collision probabilities for each possible flight path. As with figure 3.1, the scale is from 0 (no probability of collision) to 1 (definite collision). Note that the towers and nacelles are static and both result in 100% collision probabilities.

3.5 Flight Path Probability Densities

Figure 3.5 indicates the probability density of where the bird's flight path will likely be based on the mean and variance of the flight path heights specified in the model inputs. This probability density answers the question "assuming a bird is flying through the the survey area, what flight path is it likely to take?". All flight paths in the horizontal direction are equally likely (by model design), but are distributed about the mean height in the vertical direction. In this figure, the mean flight path height is equal to the highest point of the turbine rotation, so only 50% of the probability density is represented, indicating that only 50% of the flight paths would fall below this height and may result in a collision.

3.6 Combined Wind Farm / Flight Path Collision Probabilities

As discussed above, figure 3.5 indicates the probable flight paths of a bird passing through the survey area while figure 3.4 indicates the probability of a collision with the wind farm for each possible flight path. By multiplying these two arrays together, flight path by flight path, we generate figure 3.6.

By summing (integrating) over the entire array, we can estimate the probability of a collision for a single bird passing through the wind farm area. After accounting for the proportion of the survey site occupied by the wind farm area, the avoidance rate of each bird, and the computed passage rate of the survey site, we generate the final estimated collision rate for the wind farm.

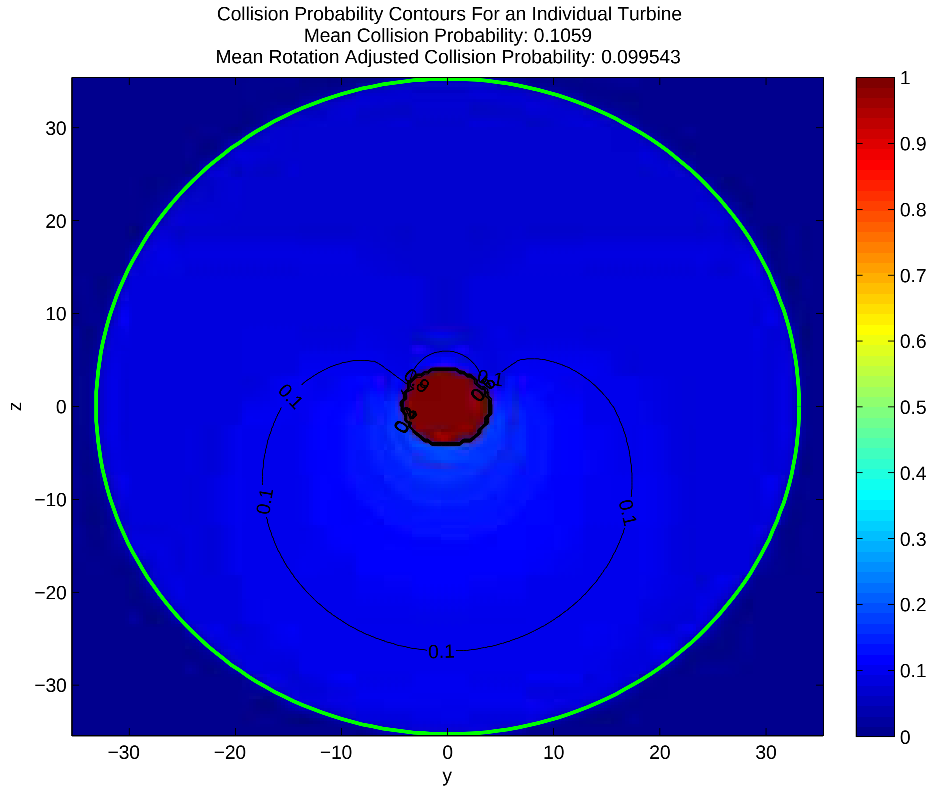

Figure 3.1:

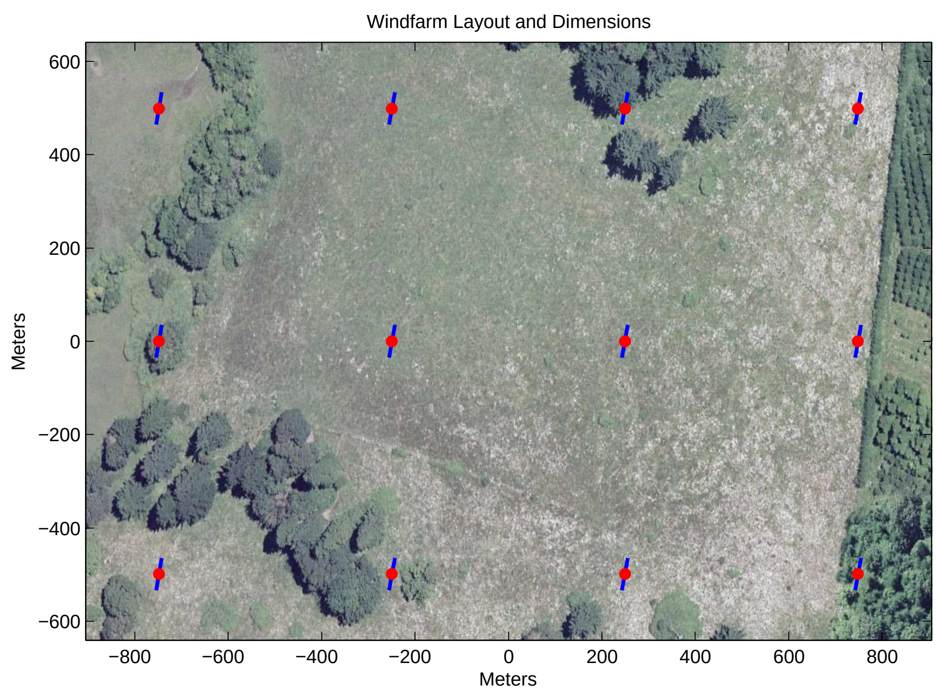

Figure 3.2:

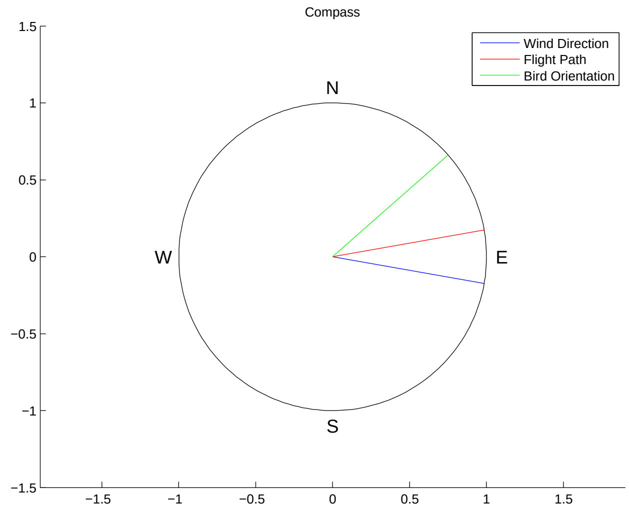

Figure 3.3:

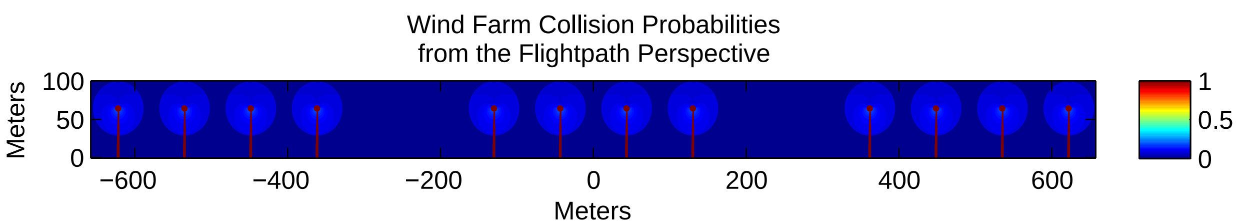

Figure 3.4:

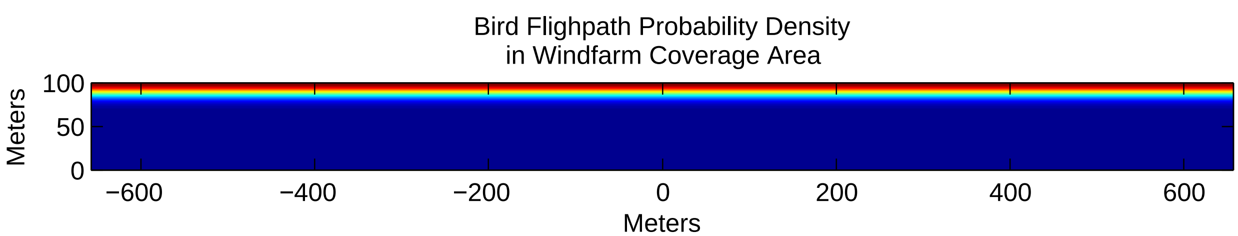

Figure 3.5:

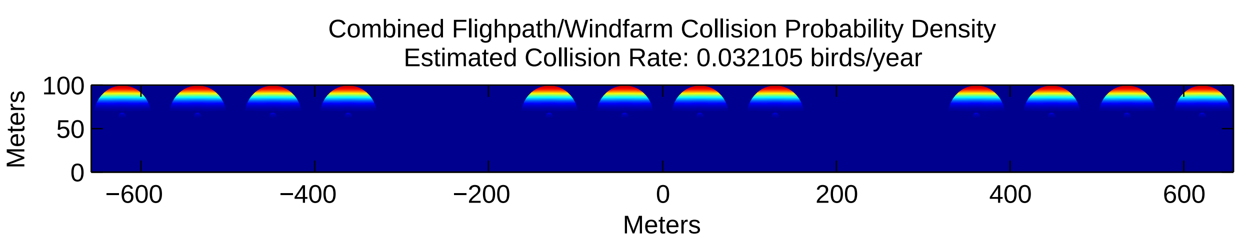

Figure 3.6:

Bibliography

[1] V. A. Tucker, "A mathematical model of bird collisions with wind turbine rotors," *ASME Journal of Solar Energy Engineering*, vol. 118, pp. 253–262, November 1996.