WaveWise: Report

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Introduction

This report will describe the creation of a Bayesian network that will be used to help determine if the surfing conditions are suitable for beginner surfers at Muizenberg Beach, South Africa. Surfing is a sport with a high barrier to entry, and is difficult to beginners to get comfortable in the ocean. Especially challenging for beginner is predicting the surf conditions beforehand to decide whether or not to go surfing in the first place. It is a common and disappointing experience to travel all the way to the beach and only discover then that the surf conditions are not ideal for surfing. To add to this surf weather forecasts are difficult to read and understand for beginners. To solve this issue, *WaveWise* has been developed to inform inexperienced surfers on whether the ocean conditions are safe and fun for surfing, thus whether they should consider going surfing on a particular day. The choice was made to focus on ocean conditions around Muizenberg beach, as it is a popular beach for learning to surf in Cape Town [Stroehlein(2021)], and due to the unique geography around it, it is especially difficult to understand the relationship between forecasted weather conditions and actual surf conditions.

1 Problem analysis

To understand how weather conditions effect the surf conditions, we must consult the domain knowledge that has been build up after many years of humans surfing. In [Scarfe et al.(2003)], [Barlow et al.(2014)], and the authors' own experiences surfing and life-guarding for many years we get this insight. Surf Conditions are determined by two main factors, wind conditions and swell conditions. Wind conditions depend on the air pressure, wind will blow from a higher air pressure to a lower air pressure, and greater pressure differentials will result in faster wind speeds [Wallace and Hobbs(2006)]. Wind conditions are relevant to surfing in the following ways:

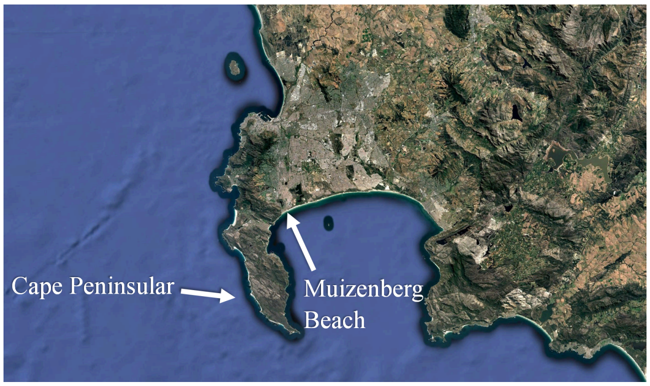
- **Offshore Winds:** Winds blowing from the land out to sea (offshore) hold up the wave face, resulting in clean, well-formed waves ideal for surfing.
- **Onshore Winds:** Winds blowing from the sea towards the land (onshore) cause waves to break prematurely, creating choppy and disorganized conditions.
- **Sideshore** winds: Winds blowing parallel to the coastline, the effect the waves in the same way as onshore winds do, thus the model will not distinguish between onshore and sideshore winds.
- **Wind Speed:** If the winds are offshore, the wind speed makes a minor impact on the waves, with a slight preference to slower winds, as surfing into strong winds can make it difficult to see. If the winds are onshore, wind speed is very important. The stronger the winds blow, the more they disrupt and disorganise the waves, making a lighter wind a strong preference in an onshore.

In Muizenberg's case, due to the direction of the coastline, any wind coming from 50°to 160°is offshore, otherwise it is onshore/side-shore. This is shown in Figure 1 (b). The Swell conditions are relevant to surfing the following ways:

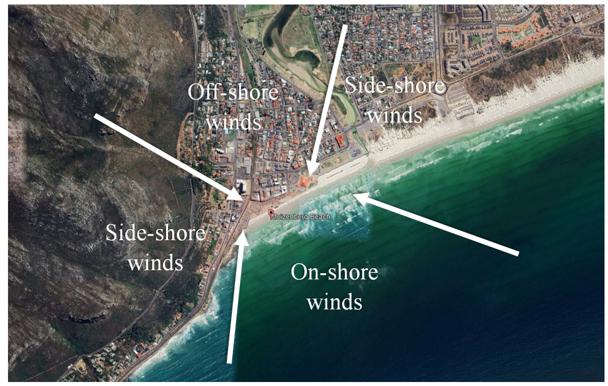
- **Wave Period:** The time interval between waves. Longer periods indicate waves that have traveled long distances, usually leading to more powerful and organized surf.

- **Wave Height:** The estimated height (amplitude) of the wave, correlated with wave period.
- **Swell Direction:** Direction the main swell is coming from. In Muizenberg's case, it is protected by the Cape Peninsula from Northerly and Westerly swells, meaning that the swell will be much smaller than predicted. This is shown in Figure 1 (a).
- **Actual wave height:** Determined on both the wave height and swell direction.

Although Tide is an important factor in surf conditions, it was not considered in this models as firstly, due to the slow sloping sandbanks of Muizenberg, the tide has only a small impact on the waves and secondly, the Tides are not a relevant to beginner surfers as they are to more experienced surfers.



(a) The Cape Peninsula Protects Muizenberg beach from much of the Northerly and Westerly Swells



(b) On-shore and off-shore winds at Muizenberg beach, as the coastline runs roughly South-West to North-East

Figure 1: How the Geography of Cape Town impacts surf conditions.

1.1 Dataset

The dataset was taken from the `https://stormglass.io/` API. A Python script was built to extract relevant weather conditions at Muizenberg every morning at 8:00 for the last 3 years. StormGlass uses a combination of weather sources, such as NOAA [Center et al.(2003)] and ICON [Rider et al.(2015)]. Based on the domain knowledge explained above and the geographical factors of Muizenberg described above, the most important weather features extracted and used in our model were:

- **Air Pressure**: Binned to Low and High
- **Wind Speed**: Binned to Low, Medium, and High
- **Wind Direction**: Binned to Off-shore (50°to 160°) and On-shore (160°to 50°)
- **Swell Direction**: Binned to Protected (200°to 360°) and Not Protected (0°to 200°)
- **Wave Period**: Binned to less than 8s, between 8s and 12s, and greater than 12s
- **Wave Height**: Binned to Small, Medium and, Big

2 Decision Network model

From evaluating the Dataset, we calculated the following probability distributions, and from using the domain knowledge described above we built the following Decision Network Model.

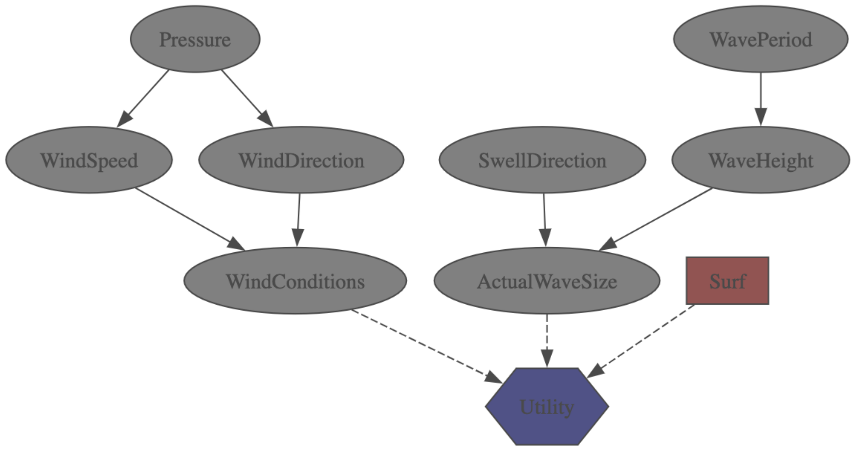


Figure 2: Decision Network

Table 1: Probability Distribution for Pressure

Pressure	Probability
Low	0.6846
High	0.3154

Table 2: Conditional Probability Distribution for Wind Speed given Pressure

Pressure		Wind Speed		
Pressure		Low	Medium	High
Low	0	0.8612	0.1012	0.0173
High	1	0.8439	0.1387	0.0145

Table 3: Conditional Probability Distribution for Wind Direction given Pressure

Pressure		Wind Direction	
Pressure		Offshore	Onshore
Low	0	0.4181	0.5686
High	1	0.3122	0.6850

Table 4: Conditional Probability Distribution for Wind Conditions given Wind Speed and Wind Direction

Wind Speed	Wind Direction	Good	Okay	Bad
Low	Offshore	0.95	0.04	0.01
Low	Onshore	0.20	0.30	0.50
Medium	Offshore	0.90	0.06	0.04
Medium	Onshore	0.05	0.25	0.70
High	Offshore	0.70	0.20	0.10
High	Onshore	0.01	0.02	0.97

This shows how when the winds are off-shore, they are likely to be good despite the wind strength, and if they are on-shore, stronger winds further deteriorate the wind conditions.

Table 5: Probability Distribution for Swell Direction

Swell Direction	**Probability**
Protected	0.8942
Not Protected	0.1057

Table 6: Probability Distribution for Wave Period

Wave Period	**Probability**
Less than 8 seconds	0.0866
8 to 12 seconds	0.6737
Greater than 12 seconds	0.2397

Table 7: Conditional Probability Distribution for Wave Height given Wave Period

Wave Period	**Wave Height**		
Wave Period	Small	Medium	Big
Less than 8 seconds	0.2947	0.5474	0.1579
8 to 12 seconds	0.1962	0.5088	0.2950
Greater than 12 seconds	0.0382	0.2548	0.7072

Table 8: Conditional Probability Distribution for Actual Wave Size given Wave Height and Swell Direction

Wave Height	**Swell Direction**	**Small**	**Ideal**	**Dangerous**
Small	Protected	0.89	0.10	0.01
Small	Not Protected	0.60	0.35	0.05
Medium	Protected	0.79	0.19	0.02
Medium	Not Protected	0.20	0.60	0.20
Big	Protected	0.10	0.50	0.40
Big	Not Protected	0.02	0.18	0.80

This shows how the protection from the Cape Peninsula greatly reduces the size impact of the Northerly and Westerly Swells.

2.1 Utility Function

The utility function is described in the following table:

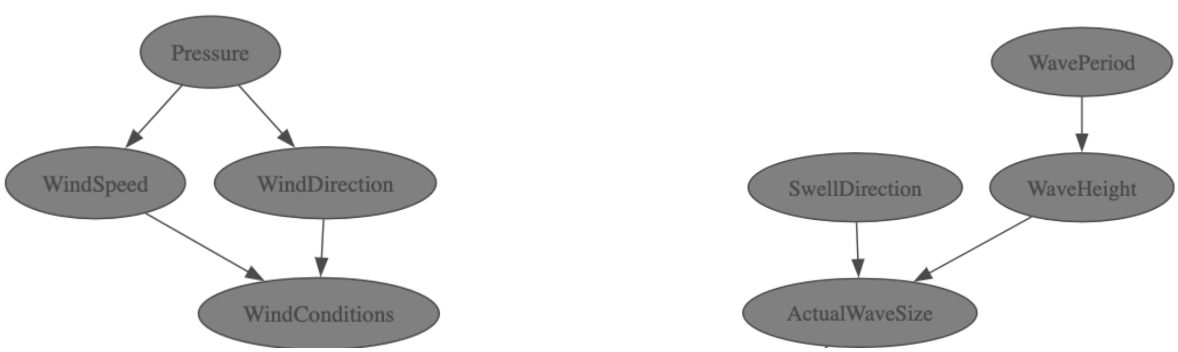
Table 9: Utility Values Based on Wind Conditions, Actual Wave Size, and Surf Status

Wind Conditions	**Actual Wave Size**	**Surf**	**Utility**
Good	Small	Yes	90
Good	Small	No	-45
Good	Ideal	Yes	100
Good	Ideal	No	-50
Good	Dangerous	Yes	-90
Good	Dangerous	No	10
Okay	Small	Yes	50
Okay	Small	No	-10
Okay	Ideal	Yes	70
Okay	Ideal	No	-15
Okay	Dangerous	Yes	-95
Okay	Dangerous	No	10
Bad	Small	Yes	-12
Bad	Small	No	6
Bad	Ideal	Yes	-10
Bad	Ideal	No	5
Bad	Dangerous	Yes	-100
Bad	Dangerous	No	10

In general, going surfing is an amazing experience, so provided the conditions were forecasted to be decent, positive utility is given. The ideal conditions (Ideal size and Good winds) gives the maximum utility. Missing the surf when it is good is a heartbreaking experience for a surfer, so if the waves were forecasted to be very good (Ideal size and Good winds), negative utility is given. Large waves may be a thrill to more experienced surfers, however they pose a serious safety concern for beginner surfers, thus if the waves are so big they might pose a threat to a beginner, very low utility is given. The rest of the utility scores lie somewhere in-between the cases described above, in general giving high scores for going surfing when the waves are good and vice versa.

3 Model testing and evaluation

Our decision network comprises two sub-Bayesian networks that the utility function depends on. These two networks are displayed in Figure 3.

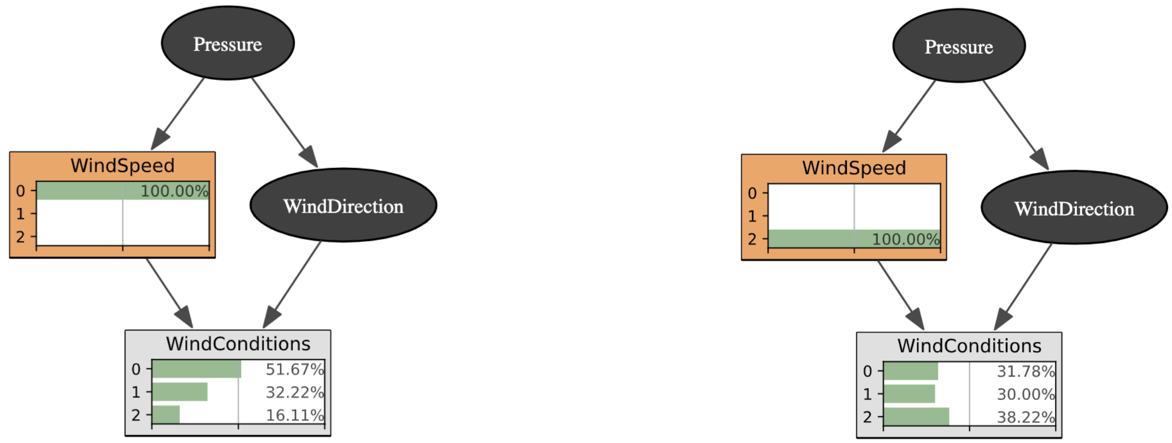


(a) Wind Condition Network

(b) Wave Size Network

Figure 3: Two Bayesian Networks that makeup the decision network

These two networks can be used to infer information on both what the wind conditions are like at the beach, as well as how big the waves are. For example, in the first network if we know the wind speed is low/high we can infer what the wind conditions are likely to be as follows:



(a) Wind condition probabilities given a low wind speed

(b) Wind condition probabilities given a high wind speed

Figure 4: Examples of inference using the wind condition network

In the wind conditions table, 0 represents the probability of good wind conditions, 1 okay wind conditions, and 2 bad wind conditions. We can see with low wind speed, the wind conditions are more likely to be good than with a high wind speed. The same idea can be used in the wave size network. For example, if we know the wave height is dangerous but we do not know the swell direction or wave period, we could infer the probabilities of the actual wave size.

3.1 Making Decisions with the Decision Network

As can be seen in figure 2, these two sub-networks can be combined and extended to produce a decision network. You can see that the wind conditions and actual wave size nodes point to a utility node. Moreover, a decision node has been added to allow decisions about whether to surf or not can be made based on the variables in the network. To show how the network can be used to make informed decisions about whether to surf as a beginner we will consider two scenarios. Firstly, suppose we know the actual wave size is going to be dangerous on a given day, we can see from Figure 5 (a) that the best decision to take is not to surf. This is expected as we would not want a beginner surfer surfing in dangerous waves. Secondly, suppose we know that the wind direction is offshore and the swell direction is protected. We can see in Figure 5 (b) that the surfer should go surfing. This is expected as well since both the wind direction and swell direction are ideal in this case.

(a) Scenario 1: should you surf given dangerous wave size

(b) Scenario 2: should you surf given offshore wind and protected swell

Figure 5: Examples of inference to make decisions with the decision network

However, these decisions do not test the model very thoroughly as they are under "ideal" observations. Figure 6 (a) displays a situation where we know the wind speed is high, which is not good for surfing. Moreover we observe that the actual wave sizes at the beach are ideal. This is an ambiguous situation as we have bad wind conditions but good wave conditions. In this scenario the model tells the surfer it is okay to surf. We expect this as the size of the waves is more important than the wind speed, especially since we do not know the wind direction. Figure 6 (b) again observes ideal wave size, but now we observe onshore winds which are not ideal for surfing. The model again predicts the user should surf, for similar reasoning mentioned previously.

(a) Scenario 3: should you surf given high wind speed and ideal wave size

(b) Scenario 4: should you surf given offshore wind and ideal wave size

Figure 6: More examples of inference to make decisions with the decision network

Conclusion

Our goal in building this decision network was to allow beginner surfers to make informed decisions about whether to surf at Muizenberg beach. Having a model that allows these new surfers to make this decision is vital as newer surfers do not have the expertise to make these decisions. Moreover, a newer surfer is at much greater risk of danger, especially if they are not able to deduce whether the surfing conditions are safe. Our WaveWise model successfully makes decisions for surfing based on both the wind conditions and wave size. This model is simple and only provides decision making for one beach. Future work could include extending the model to other beaches, as well as incorporating more variables to make more informed decisions.

References

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