Machine learning based study of mirages

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Institutes:
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  [2]Eötvös Loránd University (Hungary)
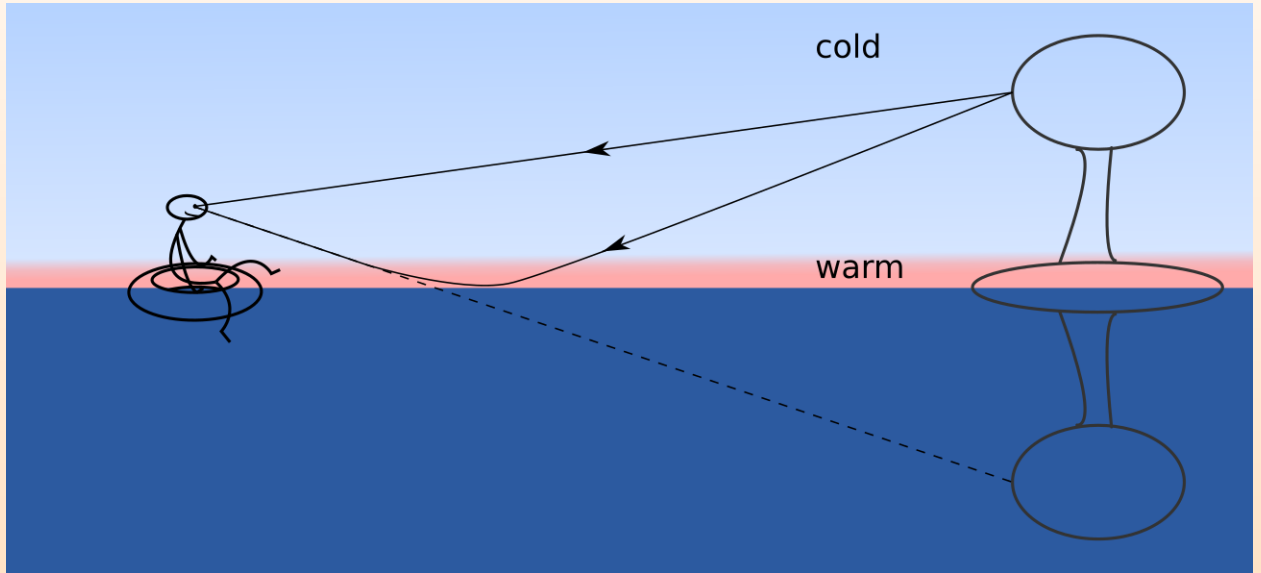 [3]Vienna University of Technology (Austria)

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Recipe of a mirage

Light rays from an object arrive to your eyes on **multiple paths**.

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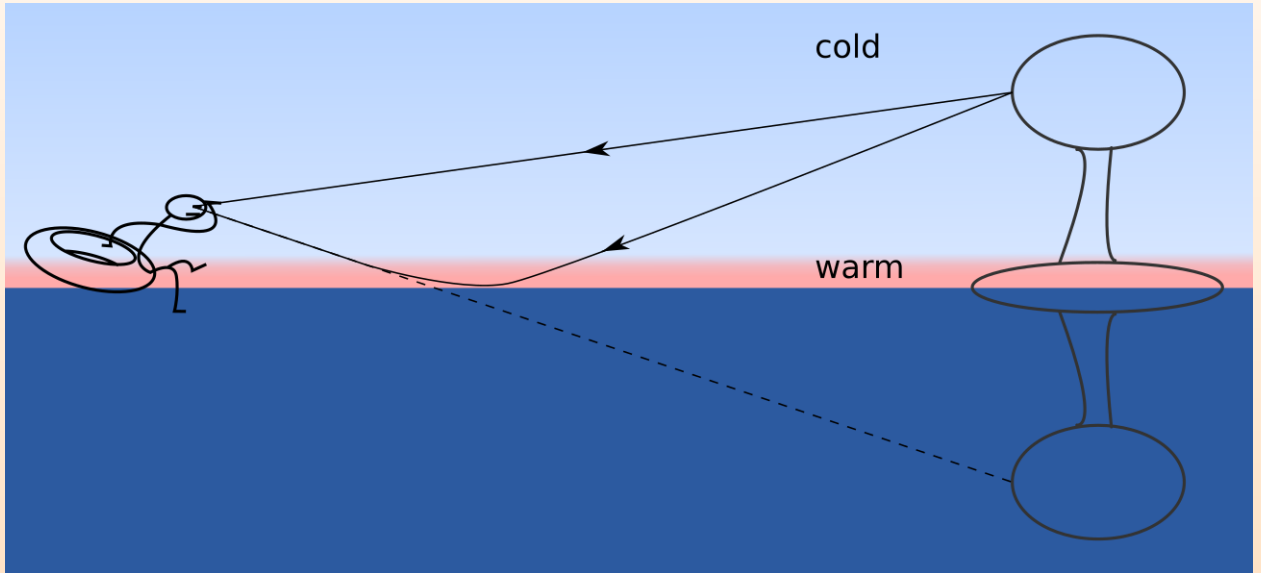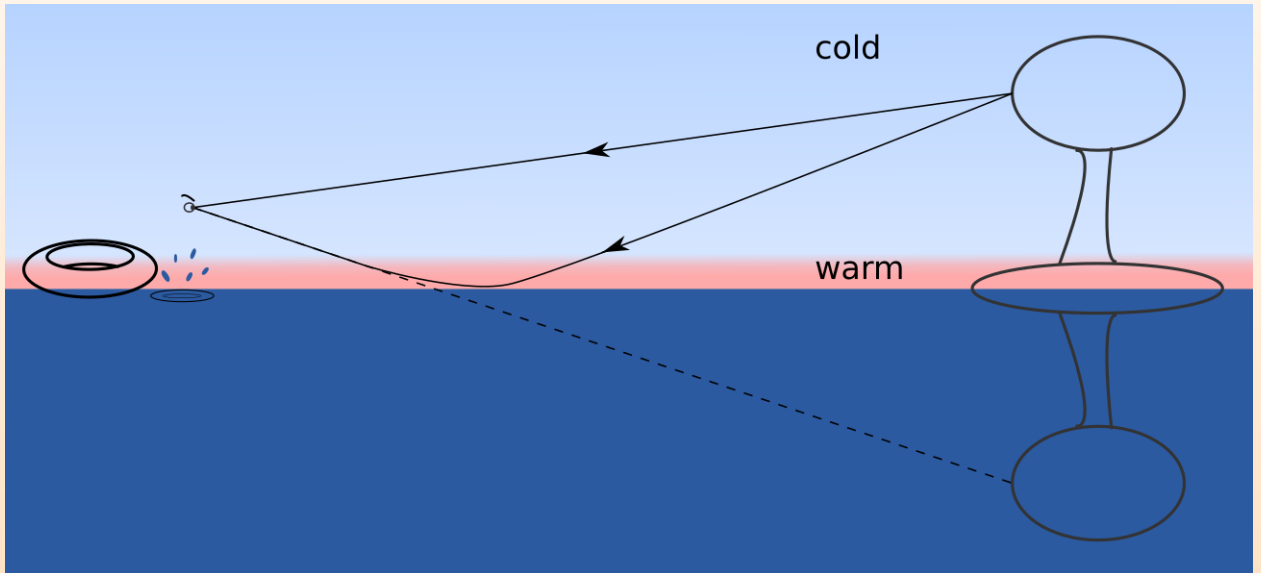
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Ingredients:

- Temperature difference between surface and air

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Recipe of a mirage
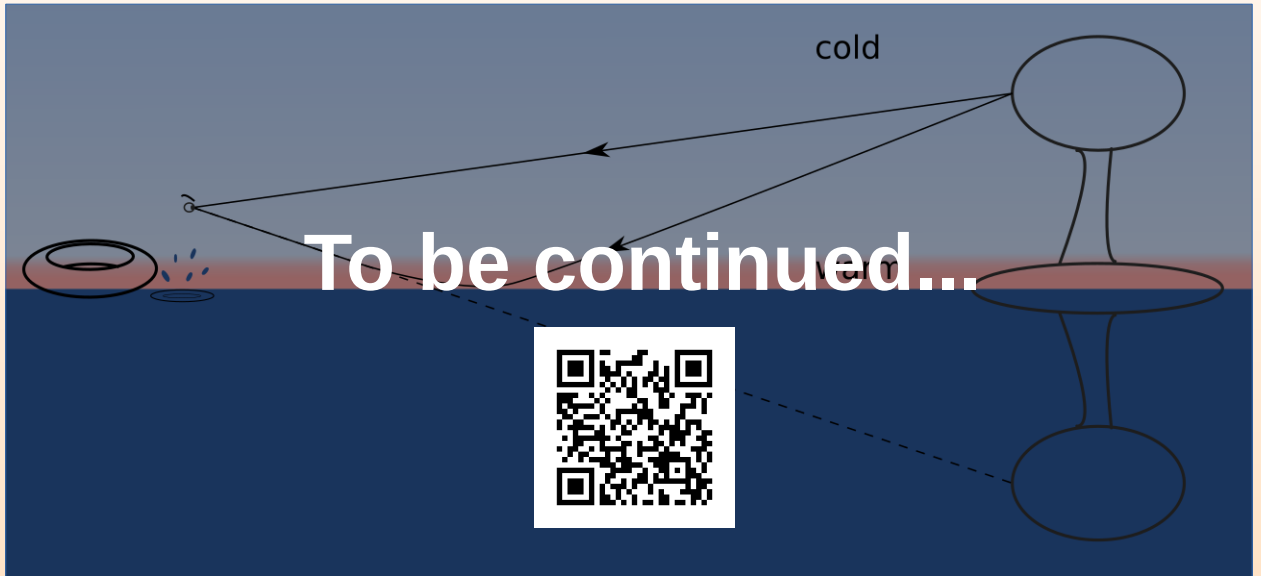
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Ingredients:

- Temperature difference between surface and air
- Good visibility conditions

Directions:

- Keep an eye out for it...

cold

To be continued...

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Keep an eye out

Hercules (1997)
https://www.imdb.com/title/tt0119282/

Photos by Katalin Horváth

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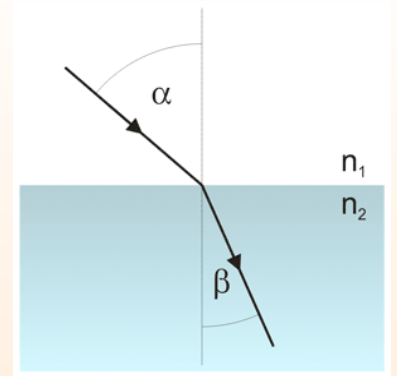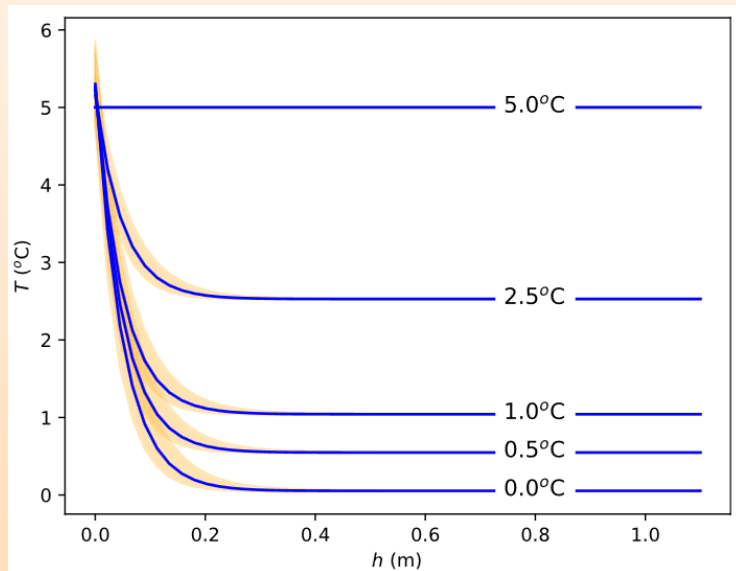
Refraction of light

A mirage is caused by the refraction of light in a medium with a **changing refractive index**.

Snell's law:
$$\frac{\sin \alpha}{\sin \beta} = \frac{c_1}{c_2} = \frac{n_2}{n_1} = n_{21}$$
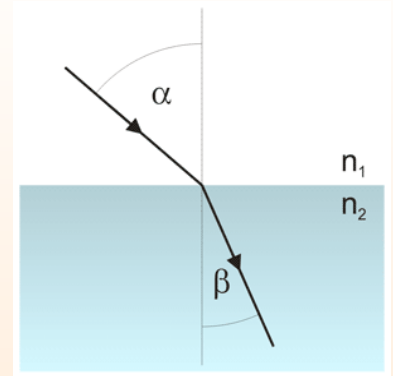
n refractive index
c *speed of light in medium*

The refractive index **depends** mainly **on temperature**.

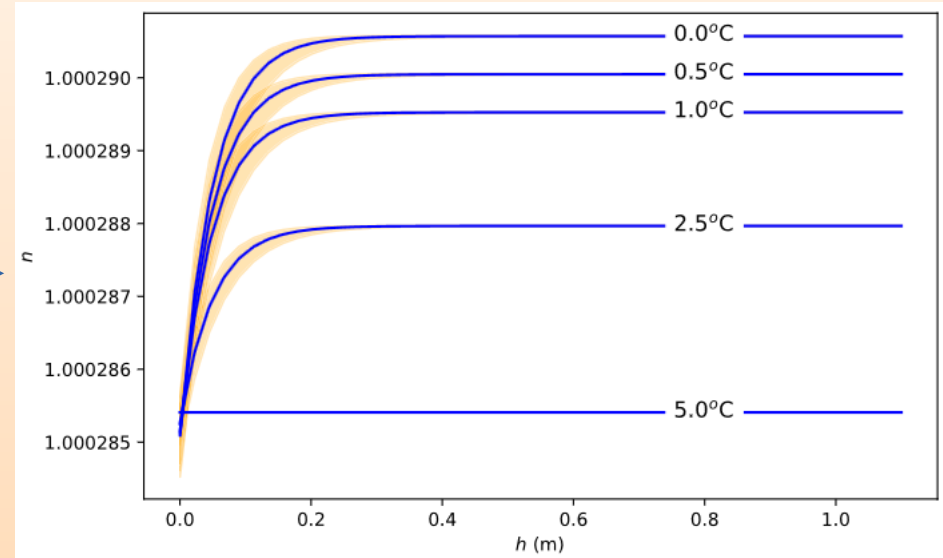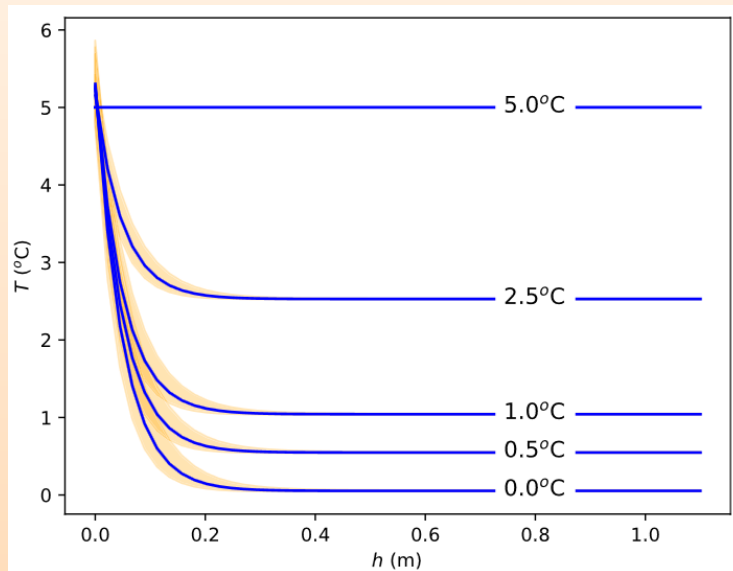*Anna Horváth*   *2024 AAPT Winter Meeting, New Orleans*

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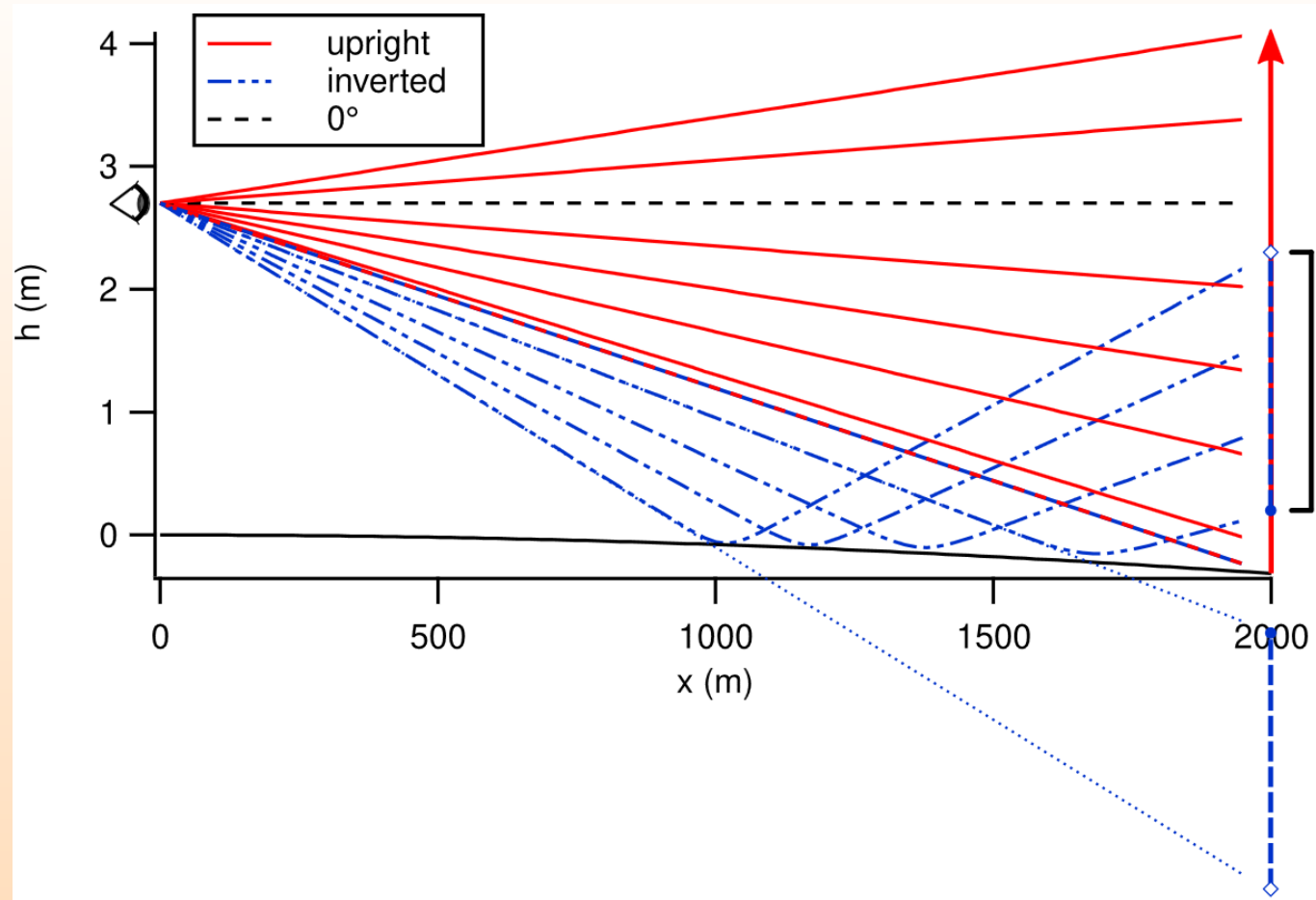
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Ray tracing

EYE → OBJECT

Calculate **change in angle** at points along the path until the ray hits the object.

Ray tracing

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Calculate **change in angle** at points along the path until the ray hits the object.

- Place image at a chosen **distance**
- Set the **temperature difference** between air and surface
- **Calculate** what you would see

Photo – with mirage

Photo – without mirage

Simulation from photo without mirage

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Ray tracing

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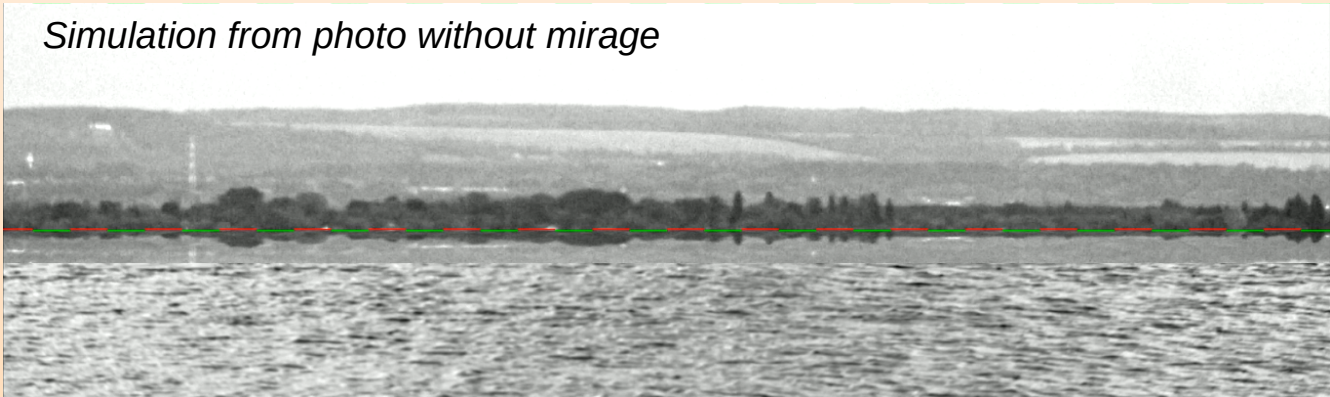- **Calculate** what you would see

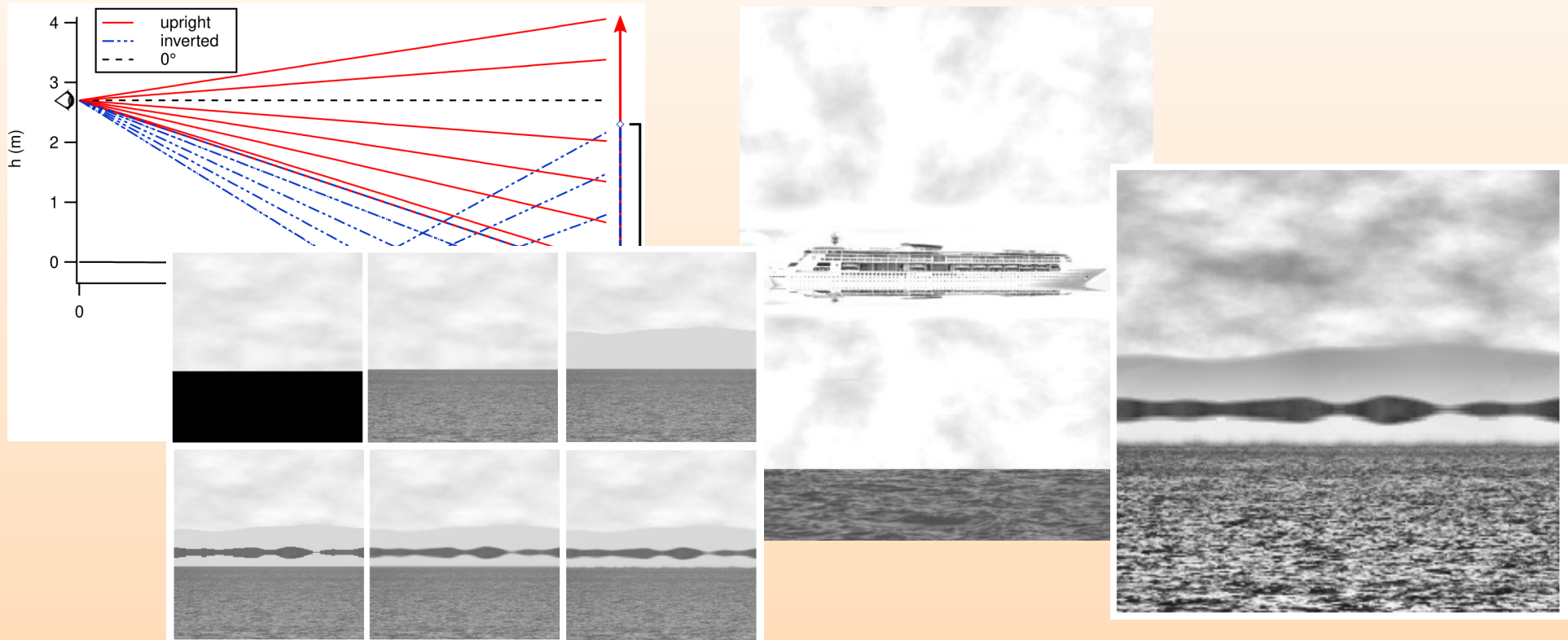*Photo – with mirage*

Photo – without mirage
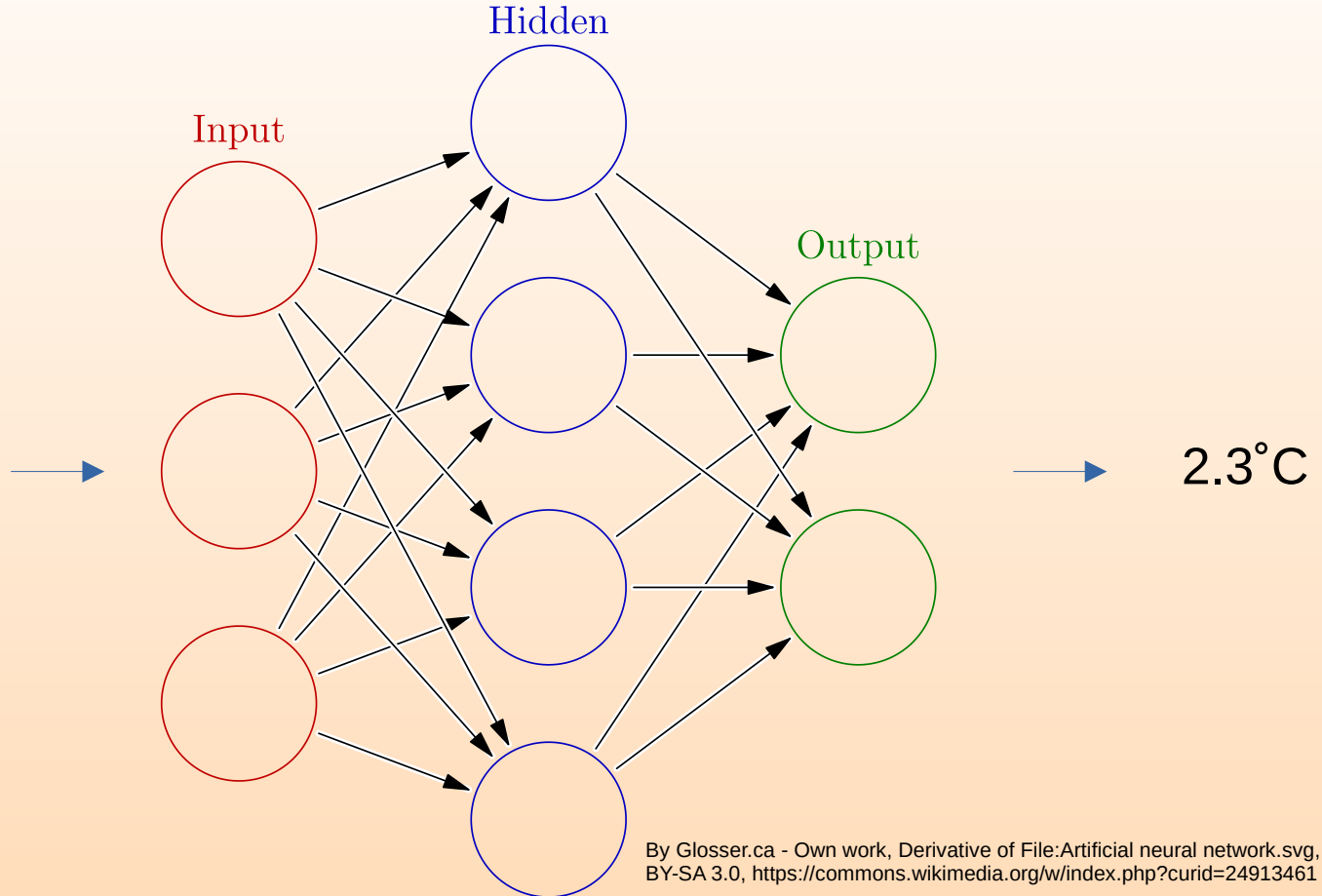
Simulation from photo without mirage

Try this with our program

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For what can you use this?

We generated **artificial images** with mirages to teach a **neural network**.

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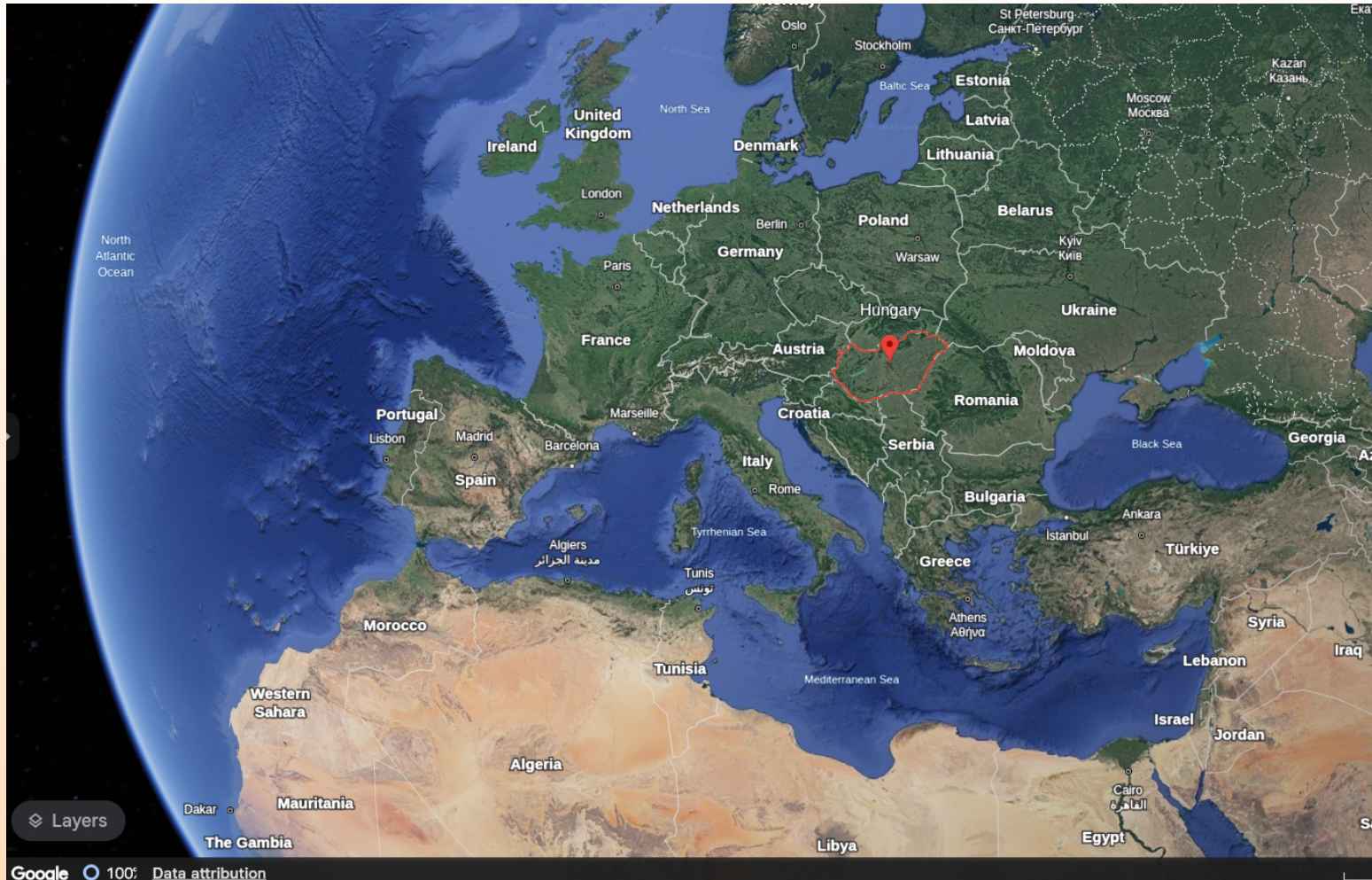
Neural network

We used the model to **predict** the **temperature difference** between the water and air.

By Glosser.ca - Own work, Derivative of File:Artificial neural network.svg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=24913461

We tried if it works

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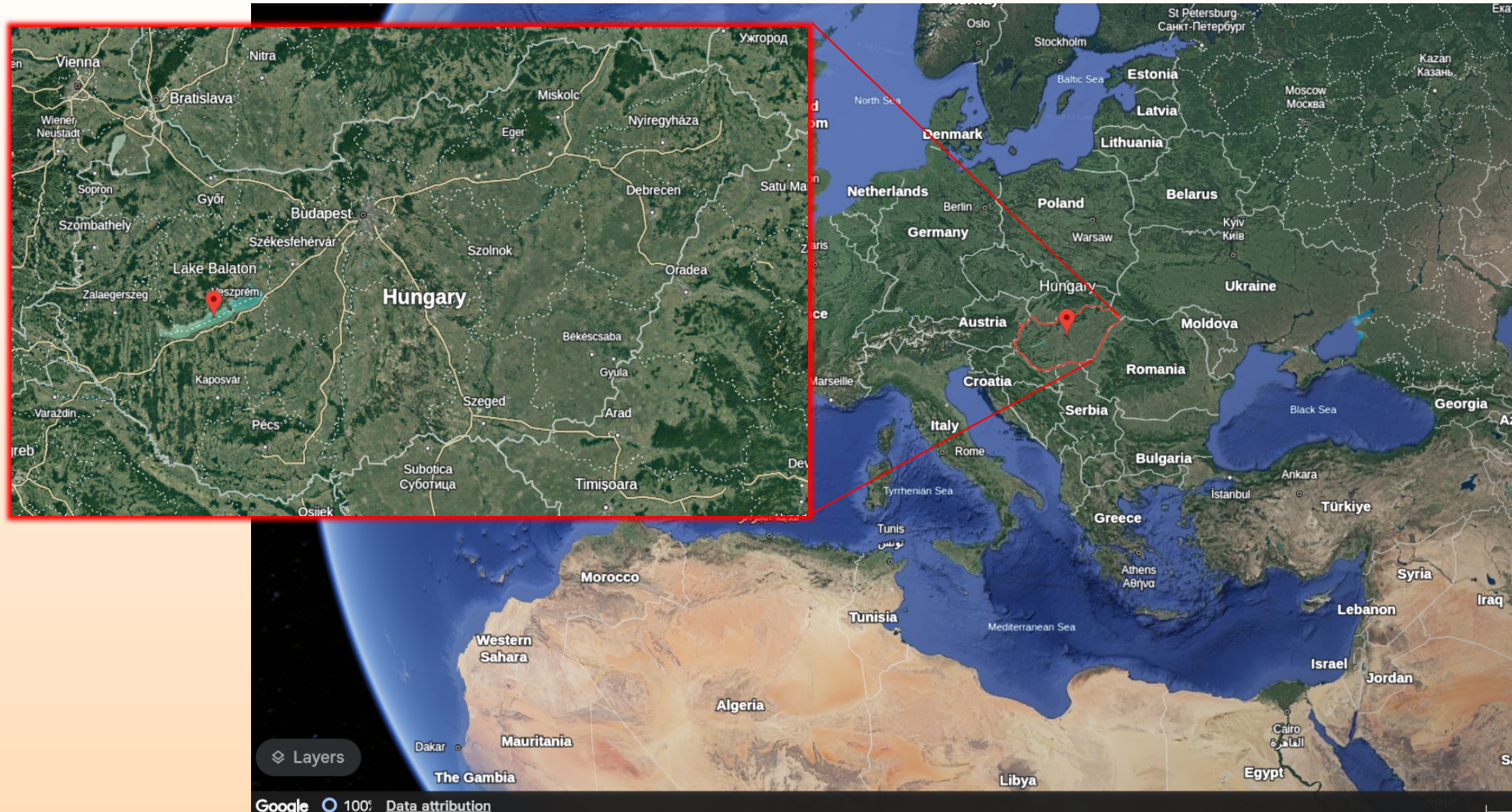
We tried if it works

Measured temperature difference: $3.2°C = 37.7°F$ **Predicted:** $3.5°C = 38.3°F$

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In a nutshell

- Mirages are caused by a **temperature difference** between surface and air
- **Refractive index** of air is almost linearly **proportional to temperature**
- Due to the **refraction of light**, rays from a point reach our eyes on **multiple paths**
- **Simulation** of mirages utilizing ray tracing
- Generating **artificial images** with mirages
- Teaching a **neural network** to **predict temperature difference** between surface and air from real photos

Thank you for your attention!