Bioelectronics: 'Sentinel' Networked Fungal Infection Surveillance Bio-Alarm System for Intensive Care Units

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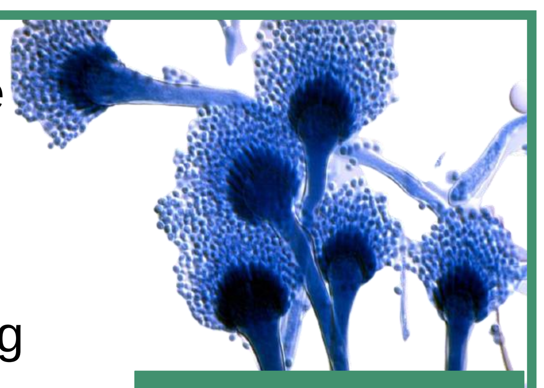
Abstract

Aspergillus Fumigatus (*A. fumigatus)* is a fungus that can cause illness in immunocompromised hosts which can easily go undetected. Therefore, a novel device, the Sentinel, has been designed to operate within hospitals, to alert medical staff if patients are at risk of becoming infected. The Sentinel was designed to be compatible with a biomimetic film, currently being developed. A modular illumination system was made to capture images of *A. fumigatus* germinating on the biomimetic film, which is positioned underneath the field of view of the camera using a cassette system. Machine learning and image processing were used to autonomously measure the average concentration, growth rate and rate of change of these properties. This data was output by the Sentinel and used to determine whether an alarm needed to be raised. Furthermore, a network was made to track the spread of *A. fumigatus* using several Sentinels, and a database was created to store all data, allowing for further lab analysis and future work.

Context and Motivation

- *A. fumigatus* is a fungus which can cause an infection called Invasive Aspergillosis (IA), which infects an estimated 300,000 people annually [1].
- The mortality rate of IA is 50%. This can increase to 100% with delays in diagnosis or misdiagnosis, which are common [2].
- Current diagnosis methods for these infections are slow and impractical.
- A method for early detection of *A. fumigatus* would reduce the occurrence of serious IA cases, reducing mortality rates and lowering the risk of *A. fumigatus* developing resistance to anti-fungal medication [3].

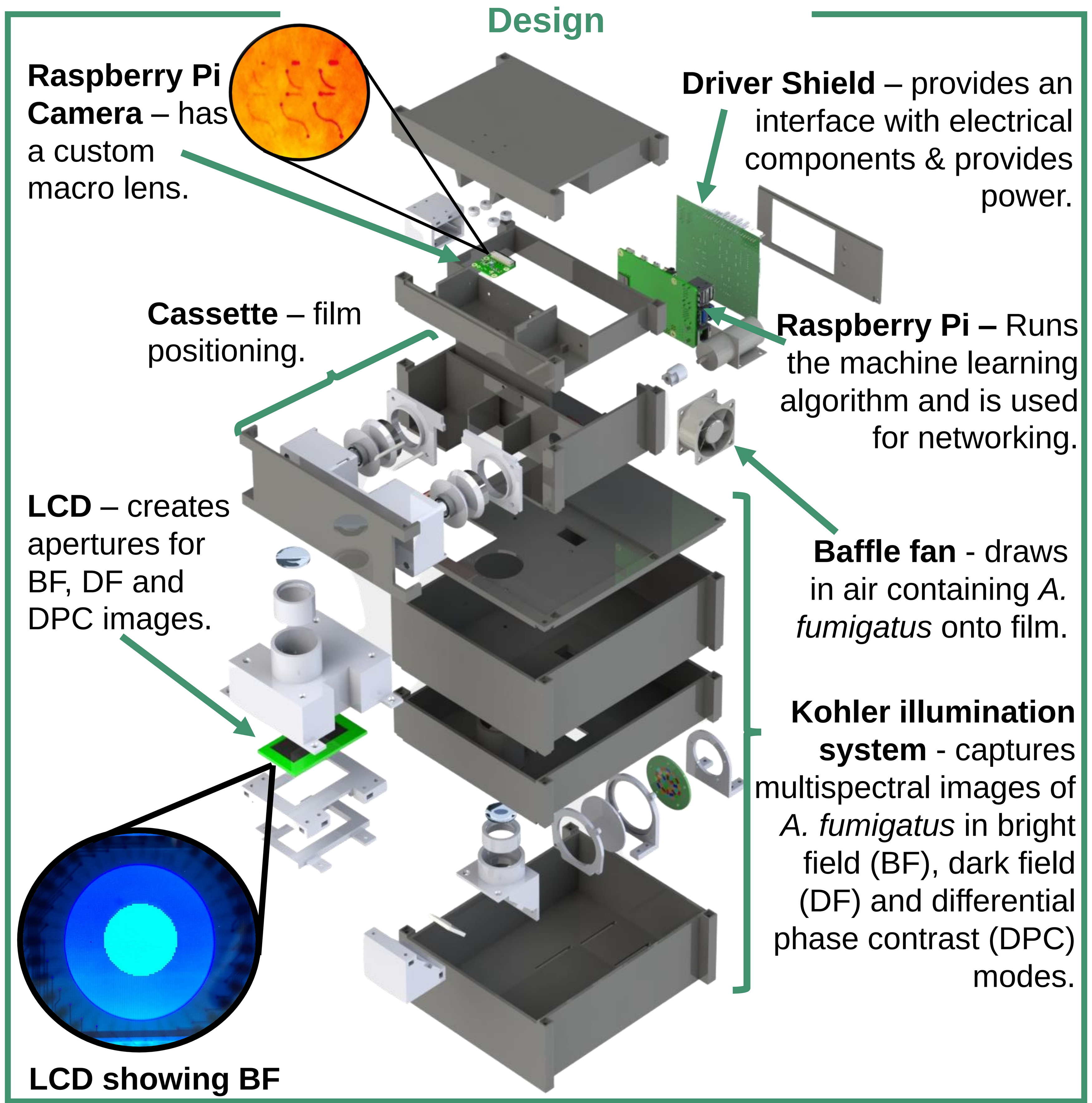


A . fumigatus

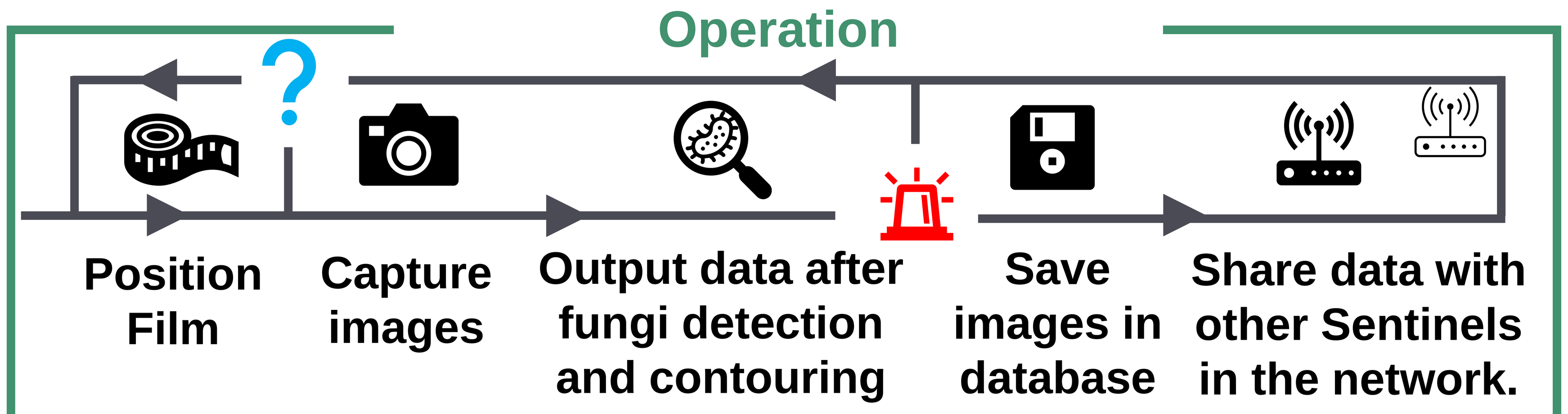
Aims

- Build a low-cost prototype of the Sentinel.
- Make it suitable for Intensive Care Units (ICU).
- Make it alert medical staff for spikes in *A. fumigatus* concentration.
- Connect it to a network of other Sentinels.
- Make it output *A. fumigatus* measurements every 6 minutes.

Design



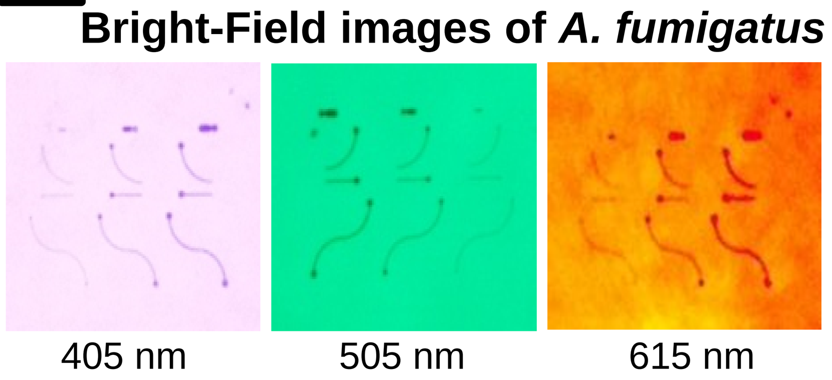
Operation



If the data output suggests patients are at risk of infection, then the Sentinel will alert medical staff, film will be advanced, and data will be output more frequently.

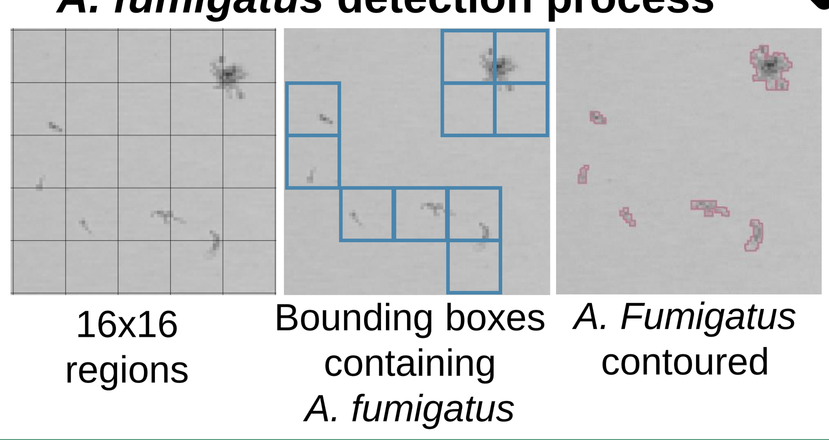
If images of *A. fumigatus* show they are too close to each other and/or overlap, blinding is occurring, and the film will be advanced.

Bright-Field images of *A. fumigatus*



Multispectral Capability

***A. fumigatus* detection process**



Results

The cassette can roll the biofilm into position and each cassette has a unique RFID tag. This ID is useful for lab analysis.

Isothermal control allowed for the biomimetic film to be kept at ± 2 ºC of a specific temperature, meaning theoretically only *A. fumigatus* should germinate.

The average concentration of *A. fumigatus* output, had a false positive rate of ≤ 1% and a false negative rate of ≤ 0.1%.
The growth rate of each *A. fumigatus* was output, with an error ranging between -0.02 μm/min and 0.09 μm/min.

An autonomous multi-spectral and multi-modal imaging system was made, which could resolve objects as small as 6 μm.

Data can be output from the Sentinel in ≤ 6 minutes, allowing for continuous monitoring of the *A. fumigatus* levels.

A network between Sentinels was created to track the spread of *A. fumigatus* through a hospital.

A database was created to store images captured by the Sentinel.

Conclusion

- The Sentinel is estimated to cost £487, which can be reduced with mass manufacture.
- The Sentinel complies with the General Data Protection Regulation, making it suitable for operating in an ICU.
- The Sentinel can raise an alarm, which increases the frequency of data output and the frequency of film being advanced.
- Sentinels can share data with each other across a network to allow for the spread of *A. fumigatus* to be tracked through a hospital.
- Data can be output every six minutes; this can become more frequent if the Sentinel raises an alarm.

Future Work

- Conduct field tests once the film is developed to determine the trigger for the alarm.
- Capture images of *A. fumigatus* taken by the Sentinel, to increase the sample size for conclusive testing of the machine learning algorithm.
- Develop a Fourier ptychographic imaging system. This would allow for larger field of view and higher resolution images, which would allow for smaller *A. fumigatus* spores to be resolved.

References

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[2] G. D. Brown, D. W. Denning, N. A. Gow, S. M. Levitz, M. G. Netea, and T. C. White, "Hidden killers: human fungal infections," *Sci. Transl. Med.*, vol. 4, no. 165, Dec. 2012, doi: 10.1126/scitranslmed.3004404.
[3] A. Srinivasan, J. L. Lopez-Ribot, and A. K. Ramasubramanian, "Overcoming antifungal resistance," *Drug Discovery Today: Technologies*, vol. 11. pp. 65–71, 2014, doi: 10.1016/j.ddtec.2014.02.005.

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