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Mcat: a multispectral cluster analysis toolkit for deep learning-based segmentation and clinical biomarker quantification of MSOT data

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Abstract

MSOT Cluster Analysis Toolkit – Mcat [1]

1) Deep learning-based segmentation of MSOT images

- identifies sample outlines from MSOT images
- deep learning (DL) approach based on a two-layer (2) neural network architecture
- retrained from scratch with manual MSOT annotations by three experts using iPhoer[3]
- pairwise Dice score shows high concordance of DL-based segmentation with experts

2) Signal-oriented analysis of MSOT images

- pre-processing eliminates motion artifacts
- defines regions of interest (ROIs)
- ROIs retrieved with DL-based segmentation
- analyzes signal intensities from whole sample
- signal-oriented approach

3) ImageJ plugin Mcat

- graph-based algorithmic structure
- graphical user interface (GUI)
- optimized data cache structure
- easily applicable and expandable

Application in Quantification of Liver Function

○ ICG – indocyanine green

○ Hb – deoxyhemoglobin

○ HbO₂ – oxyhemoglobin

○ analysis of specific regions of interest (ROIs)

○ manually defined regions of interest (ROIs)

○ extracts signal intensity features

○ are under the curve (AUC) statistics

○ tissue-oriented analysis

○ fails to identify differences between healthy (Sham) and septic (PCP) animals

○ even small positional changes lead to highly different intensity values

○ tissue-oriented analysis prone to user bias and often not reproducible

○ main signal kinetics are extracted by k-means clustering

○ weighted average curves (WACs) of signal kinetics with net increase for each animal

○ weights are pixel frequencies of the respective cluster center

○ AUCs of signal kinetics measurements

○ main signal kinetics as extracted by k-means clustering

○ WACs of signal kinetics with net increase

○ AUCs of treatment groups

○ $p < 0.001$

○ in contrast to tissue-oriented analysis we find significant difference between groups

○ analysis of morphological shape descriptors

○ e.g. particle number, validity for each signal kinetic classification with support vector machine

○ high accuracy for animals with ambiguous kinetics

○ spatial biomarker distribution allows discrimination of healthy and diseased animals [4]

○ signal-oriented analysis allows evaluation of new drugs *in vivo*

○ targeted delivery of PON-1 inhibitor restores liver function in preclinical sepsis as found by MSOT [5]

○ utilization of Mcat in personalized medicine and drug development

○ principle of targeted drug (L-LipoAs) delivery

○ AUC statistics for treatment groups

○ pairwise effect size of treatment group AUCs

○ $p = 0.001$

○ images adapted from [6]

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References

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- [2] Springer et al., *Nat Methods* 18 (2021), 100–106
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