Accelerating pore-scale flow simulations with a machine learning approach

Arash Rabbani, Masoud Babaei

University of Manchester

SPE London evening meeting, 26 Feb 2019

The University of Manchester

- The largest campus-based university in the UK-over 39,000 students.
- The largest university library in the country
- £650 million investment in superior facilities
- Highly rated in the 2014 research assessment (85% judged to be ‘world leading’ or ‘internationally excellent’).
- Teaching rated as “Excellent”
- Schlumberger Centre of Excellence, BP and Shell core university

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Petroleum Engineering overview

- Energy Institute accredited programmes (since June 2014)
  - 3 year BEng in Petroleum Engineering (partial CEng status)
  - 4 year MEng in Petroleum Engineering (full CEng status)

- Programme started in 2006/07 and grown into one of the UK's leading undergraduate programmes in Petroleum Engineering

- Run jointly between "School of Earth and Environmental Science" and "School of Chemical Engineering and Analytical Science"

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energy institute Learning Affiliate

energy institute Accredited Course

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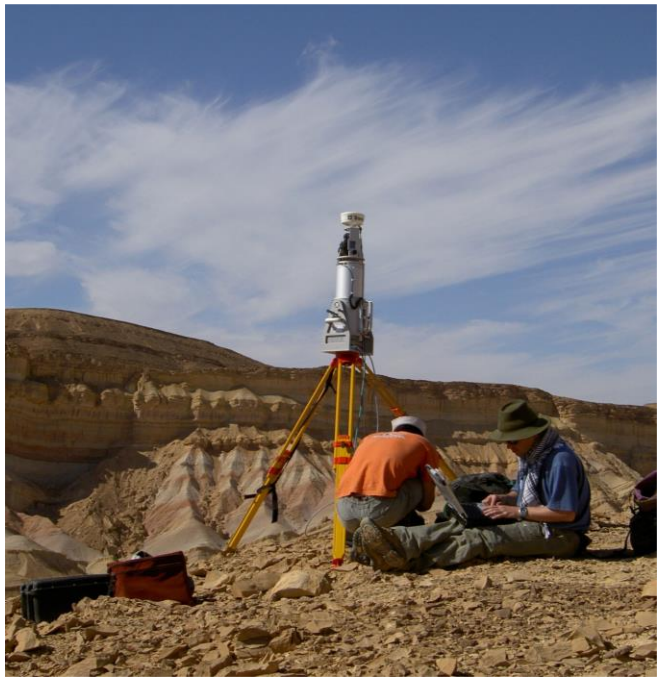
Petroleum Engineering at University of Manchester; *joint-collaboration of CEAS and SEAES*

School of Chemical and Analytical Science (CEAS)

- Birth place of Chemical Engineering
- Largest Chemical Engineering School in the UK
- Morton Laboratory- pilot scale chemical manufacturing plant
- James Chadwick Building- new teaching facilities
- Research and teaching excellence
- 3 dedicated academic staff in Petroleum Engineering

School of Earth and Environmental Science (SEES)

- One of the largest Earth Sciences teaching and research centres in the UK
- 47 academic staff, 20 Professorial
- 140 undergraduates per year. High staff:student ratio
- Exceptional facilities and resources for teaching
- Access to research equipment & industry standard software



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MASOUD BABAEI
Research Group

Research Grants

1 - **British Council *Newton Institutional Link*** with Turkey April 2018 call (£247,721 total – UoM: £104,788, **PI: M Babaei**) - Soil salinity and sodicity management by sustainable irrigation practices in Konya Plain, Turkey.
Collaborators: Prof Nadim K Copty, Boğaziçi University, Prof Günay Erpul, Ankara University and and Dr Manoj Menon, University of Sheffield
Funding rate: 11.4% for Grants Awarded: Newton Institutional Links
Duration: 24 months beginning April 2019

2 - **American Chemical Society *Petroleum Research Fund*** #59217-ND9 ($110k, **PI: M Babaei**), *A better understanding of noble gas fractionation during natural gas migration in tight rock and water-saturated crust through two phase flow modelling.*
Collaborators: Prof Andrew J Masters at the University of Manchester, Dr Dong Chen at the Chinese University of Petroleum, Beijing, and Dr Ali Takbiri, West Virginia University
Duration: 24 months beginning 15/10/18

3 - **Royal Society *International Exchanges*** 2017 Cost Share (China), IEC\NSFC\170002, (£6,178, **PI: M Babaei**) *Gas transport behaviour in multiple formations of tight sandstone, shale and coal during gas co-production.*
Duration: 24 months beginning 31/03/18
Collaborators: Dr Majid Sedighi at the University of Manchester, and Dr Dong Chen at the Chinese University of Petroleum, Beijing

4 - **Engineering and Physical Science Research Council *First Grant*** EP/R009678/1 (£100,961, **PI: M Babaei**) *Multiscale modelling of miscible interfaces: Application on surfactant-enhanced aquifer remediation.*
Duration: 18 months beginning 01/01/18
Collaborators: Dr Fabrice Golfier, University of Lorraine, France
Funding rate: 43% for First Grants of Engineering Prioritisation Panel Meeting, August 2017, overall the success rate of EPSRC First Grant was 30%

Dr Masoud Babaei

Lecturer in Petroleum/ Engineering at the University of Manchester

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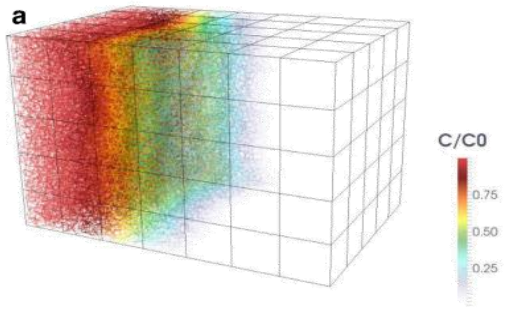
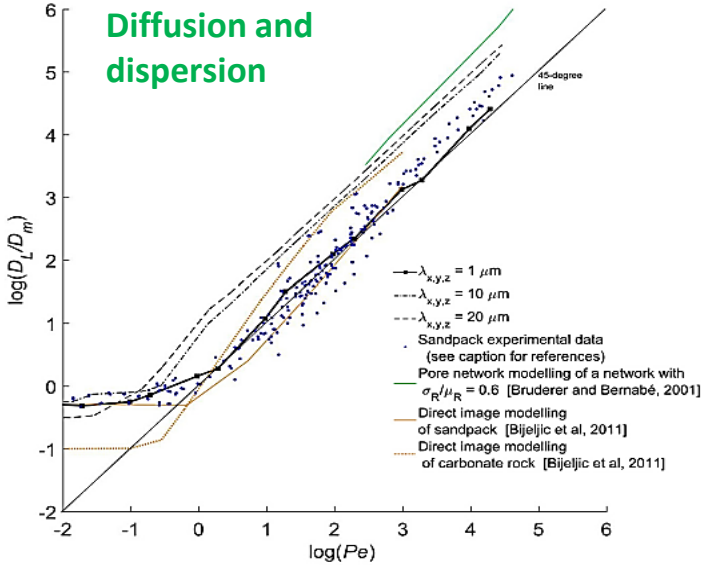
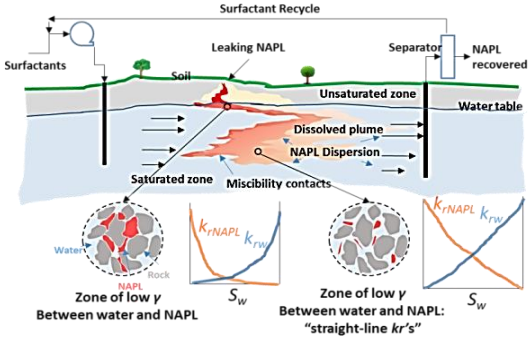
Research expertise and interests

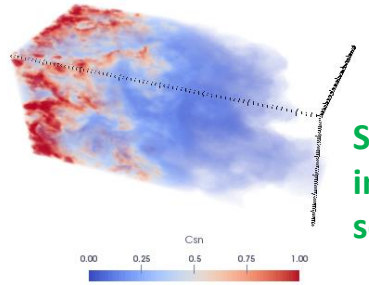
1 – Groundwater flow, soil contamination and remediation (active EPSRC project)
2 – Hydrocarbon recovery and Enhanced Oil/Gas Recovery using surfactant solutions (an active PhD project)
3 – Shale gas transport in tight pores, tracing technologies using noble gas components (active ACS project and a PhD project)



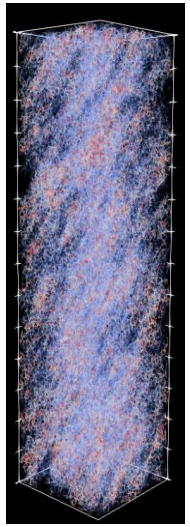
Diffusion and dispersion

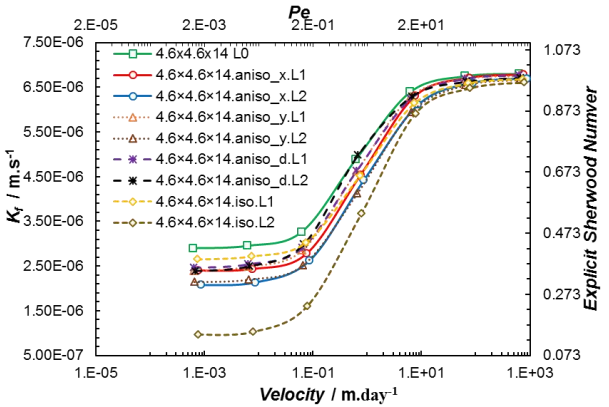






Surfactant injection into contaminated soil

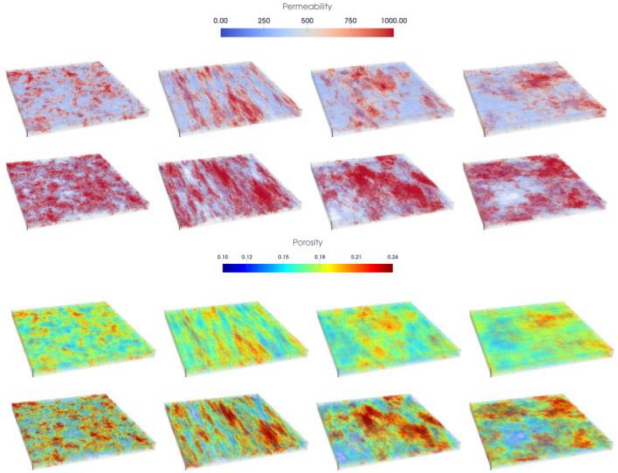




NAPL clean-up

Research expertise and interests

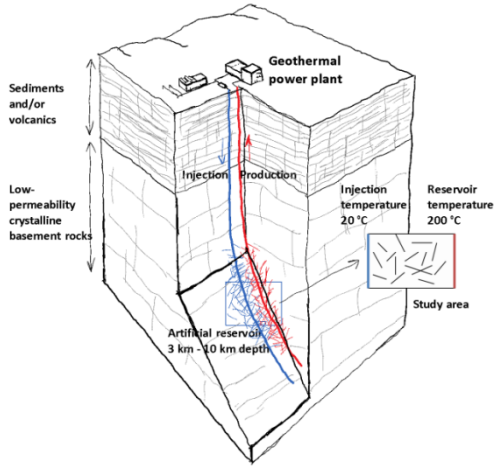
4 – Geothermal heat recovery under uncertainty

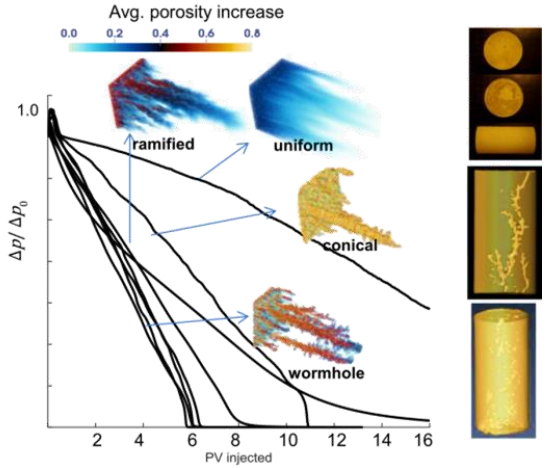


5 – CO_2 storage

6 – Reactive transport (acid injection in rock and CO-water-rock interaction)

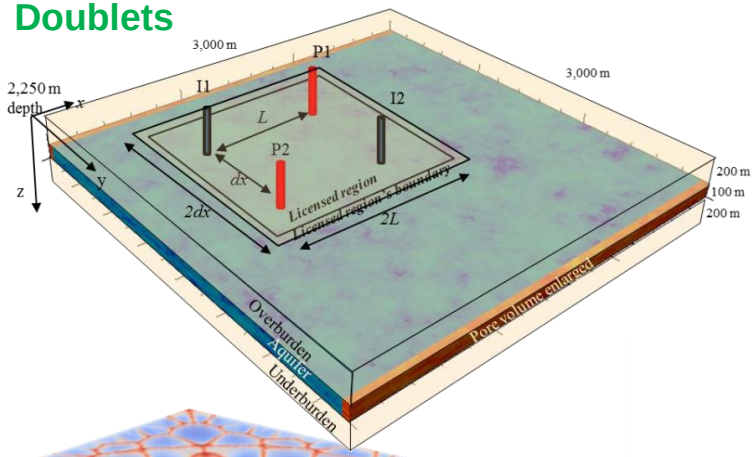
Enhanced Geothermal Systems

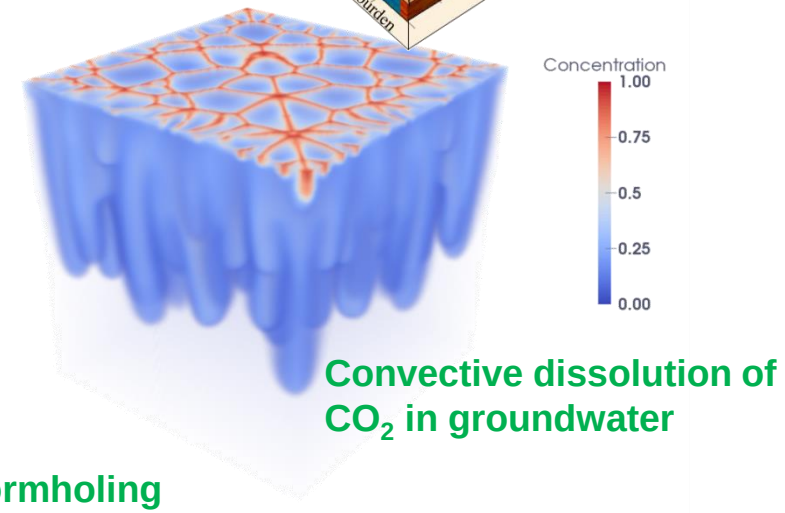




Wormholing process

Doublets





Convective dissolution of CO_2 in groundwater

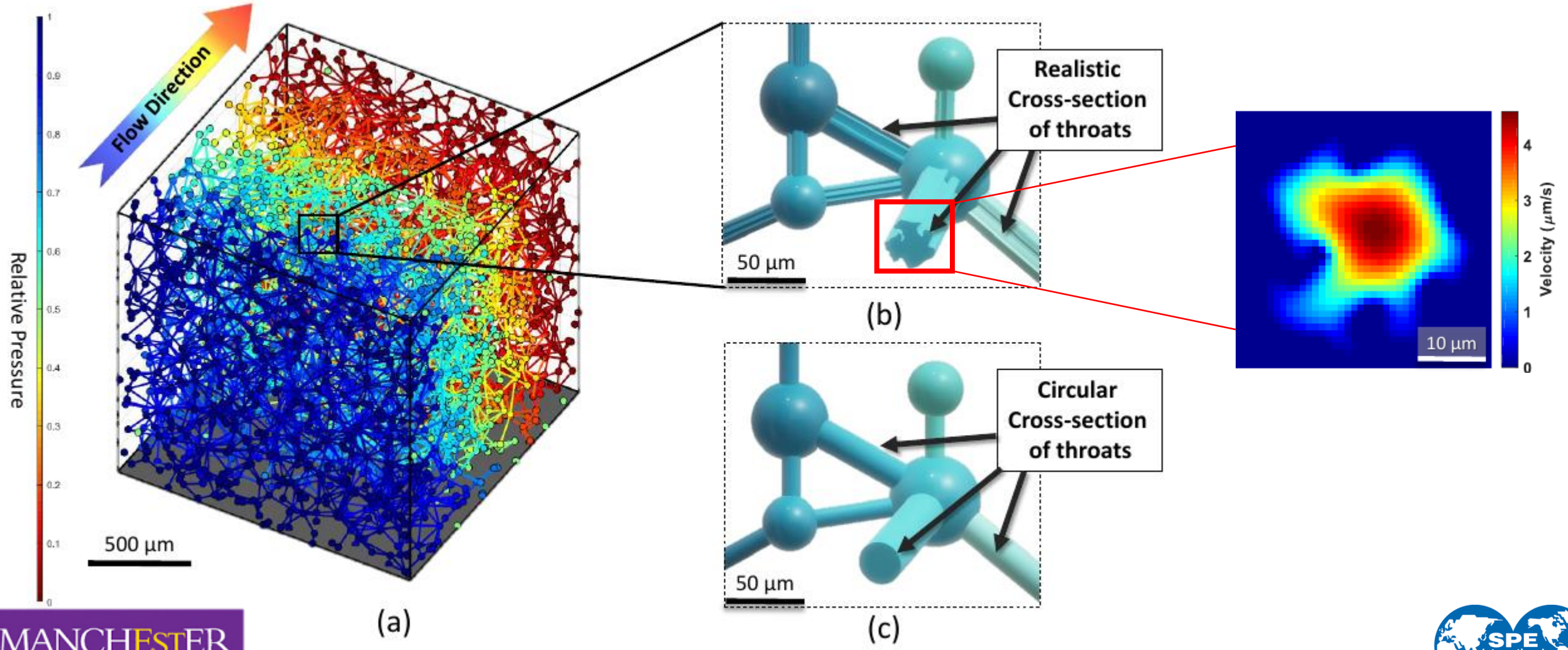
Motivations

- Big data issue
- Computational limits
- Accuracy
- Avoiding unnecessary repeats

Problem Statement

Pore Network Model

LBM Simulation



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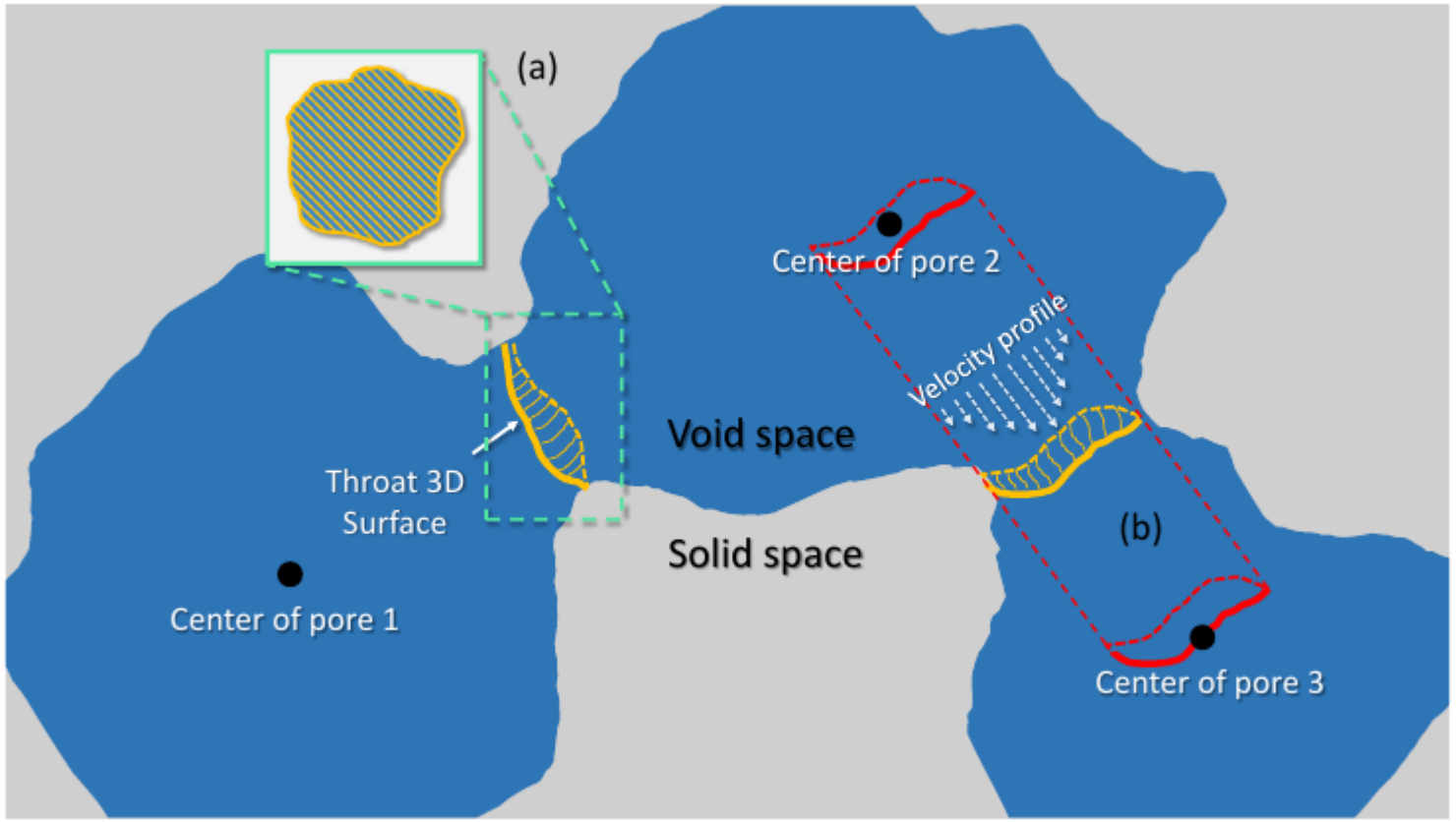
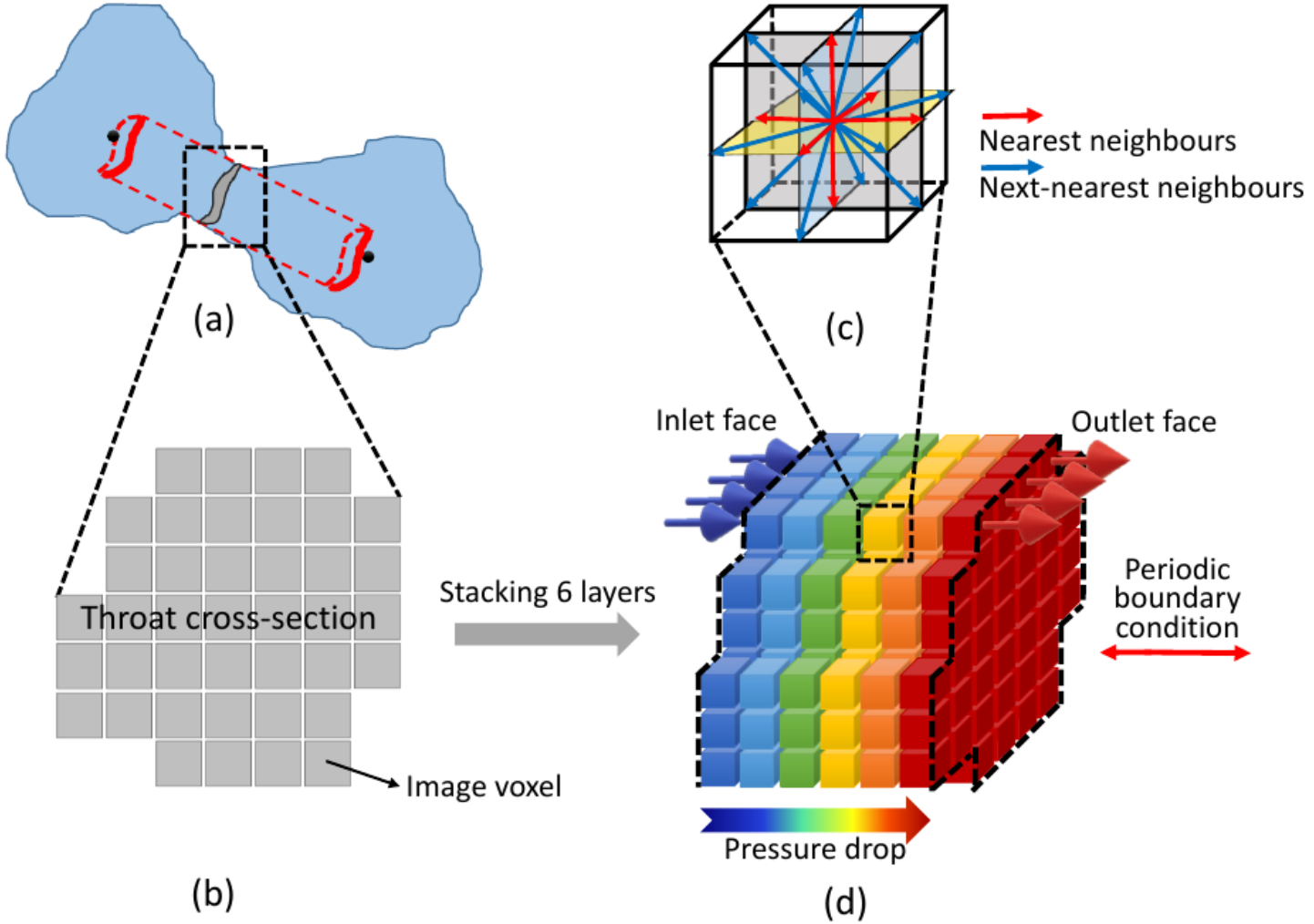
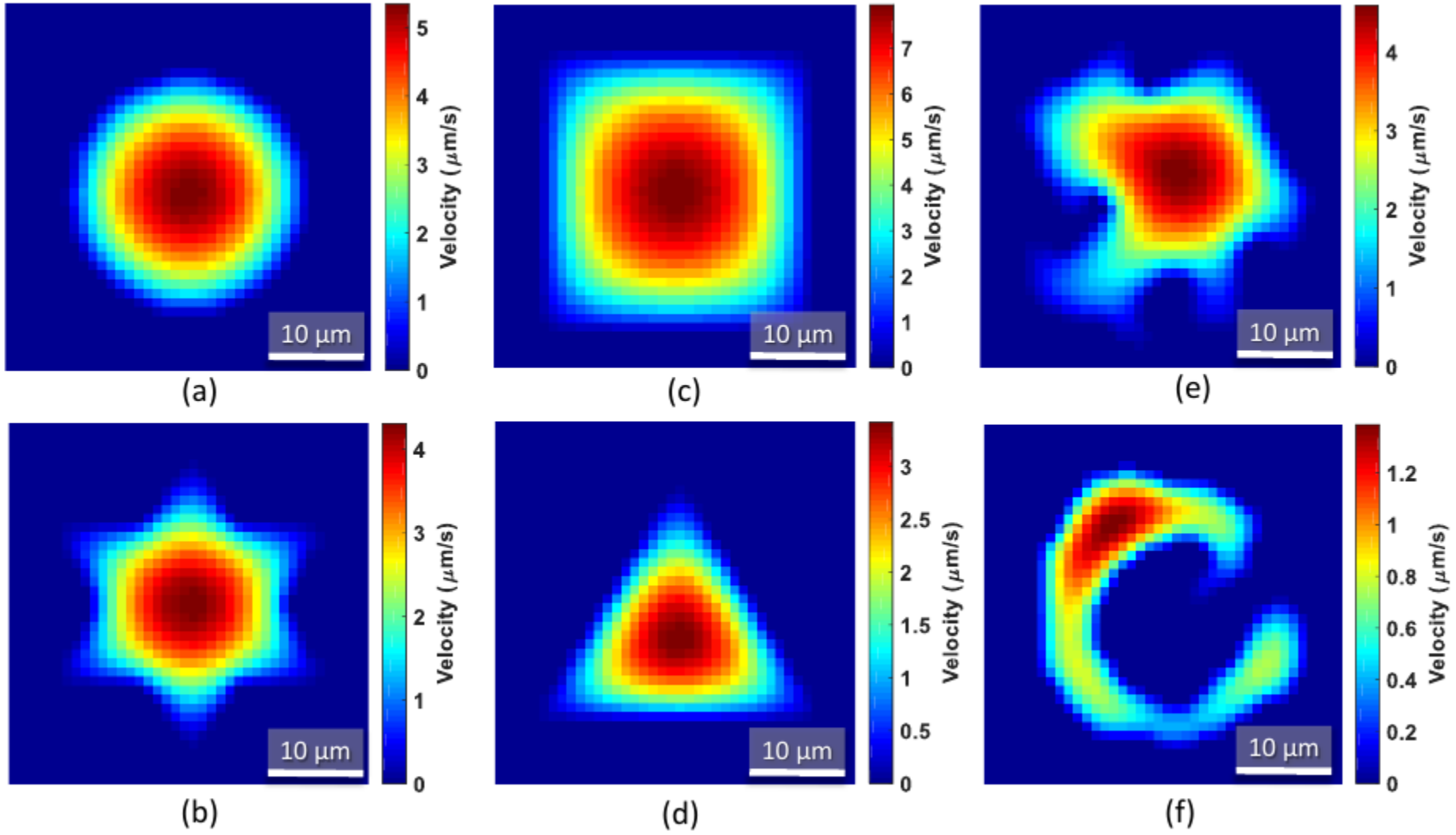
Assumptions



LBM Simulation



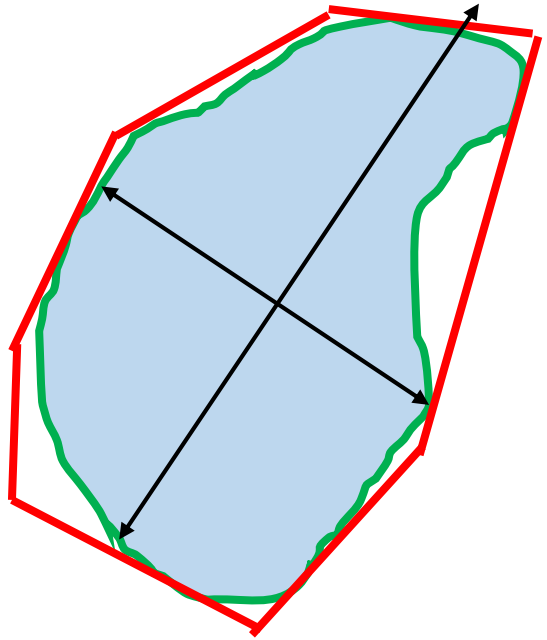
Throat velocity profile



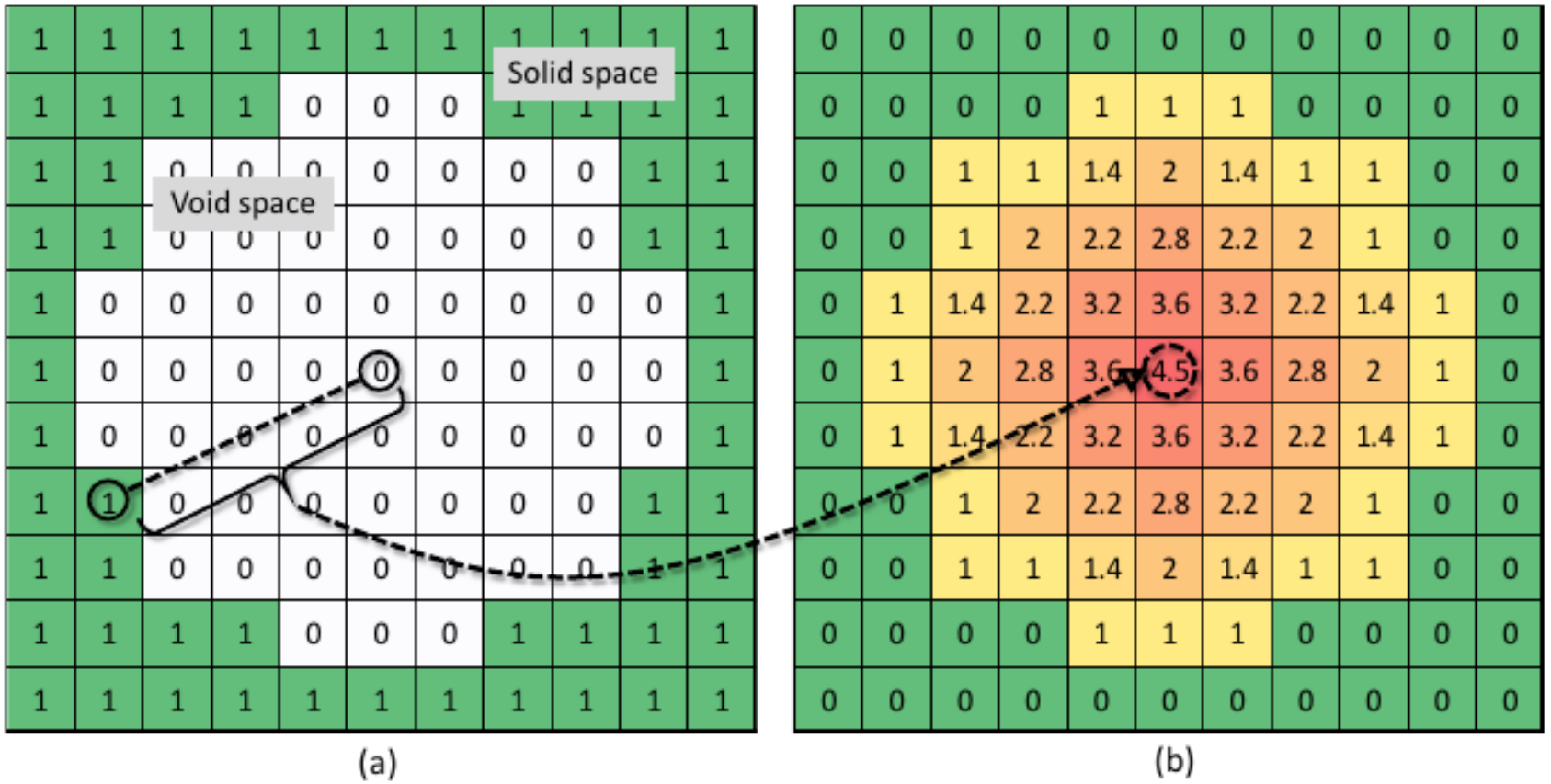
Machine Learning approach

Throat geometrical features

No.	Feature	Feature Description
1	Cross–section area ($pixel^2$)	Surface area of the 2–D projection of throat
2	Wetted perimeter ($pixel$)	Perimeter of the 2–D projection of throat
3	Axes ratio	Ratio between the major and minor axes of the throat which is always greater than 1
4	Equivalent diameter ($pixel$)	Diameter of the circle with the same area as the throat
5	Solidity	Area of the throat convex hull divided by the throat area
6	Hydraulic radius ($pixel$)	Throat area multiplied by two divided by throat wetted perimeter
7	Mean distance ($pixel$)	Non–zero average of the throat distance transform



Distance Transform



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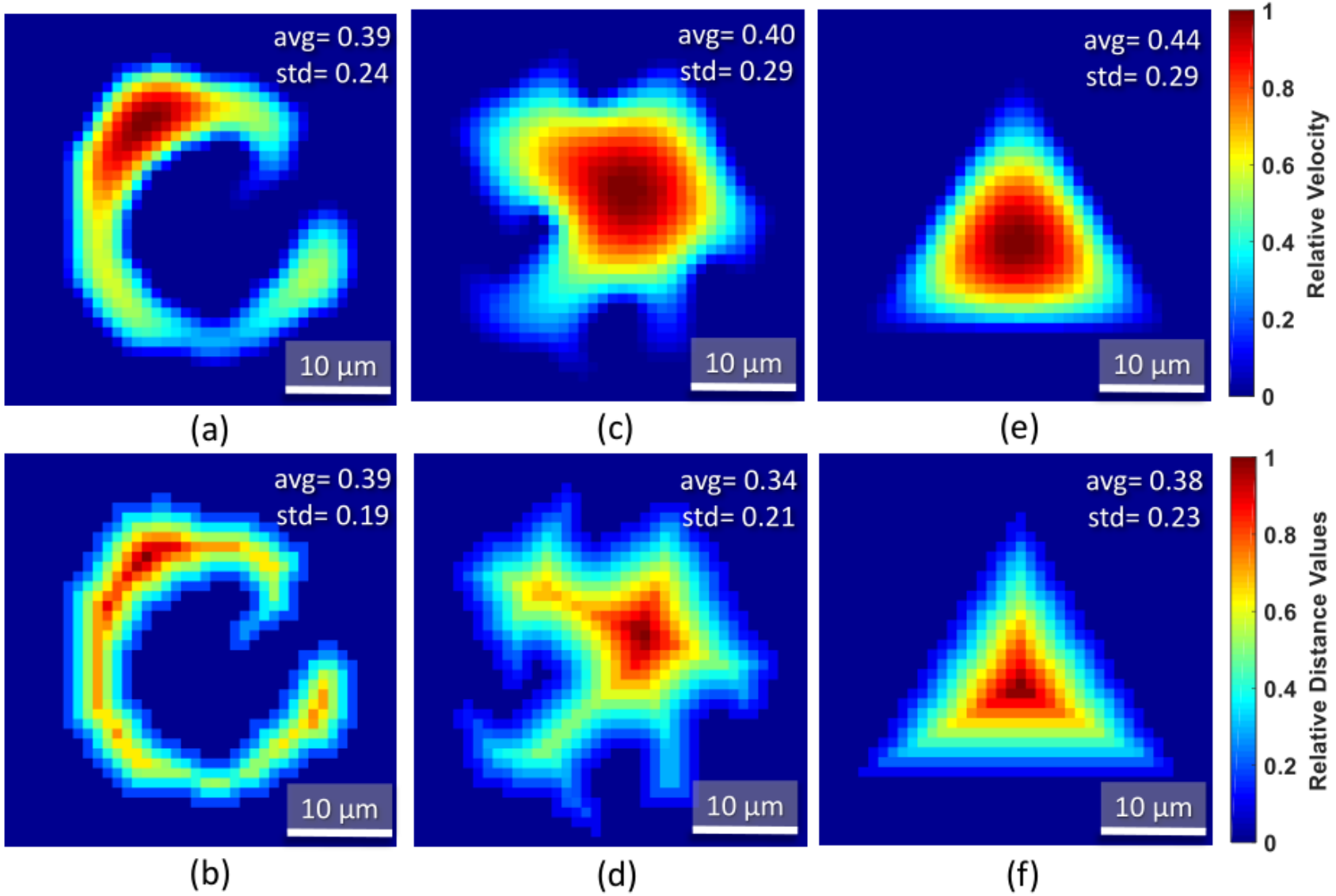
Physical justification



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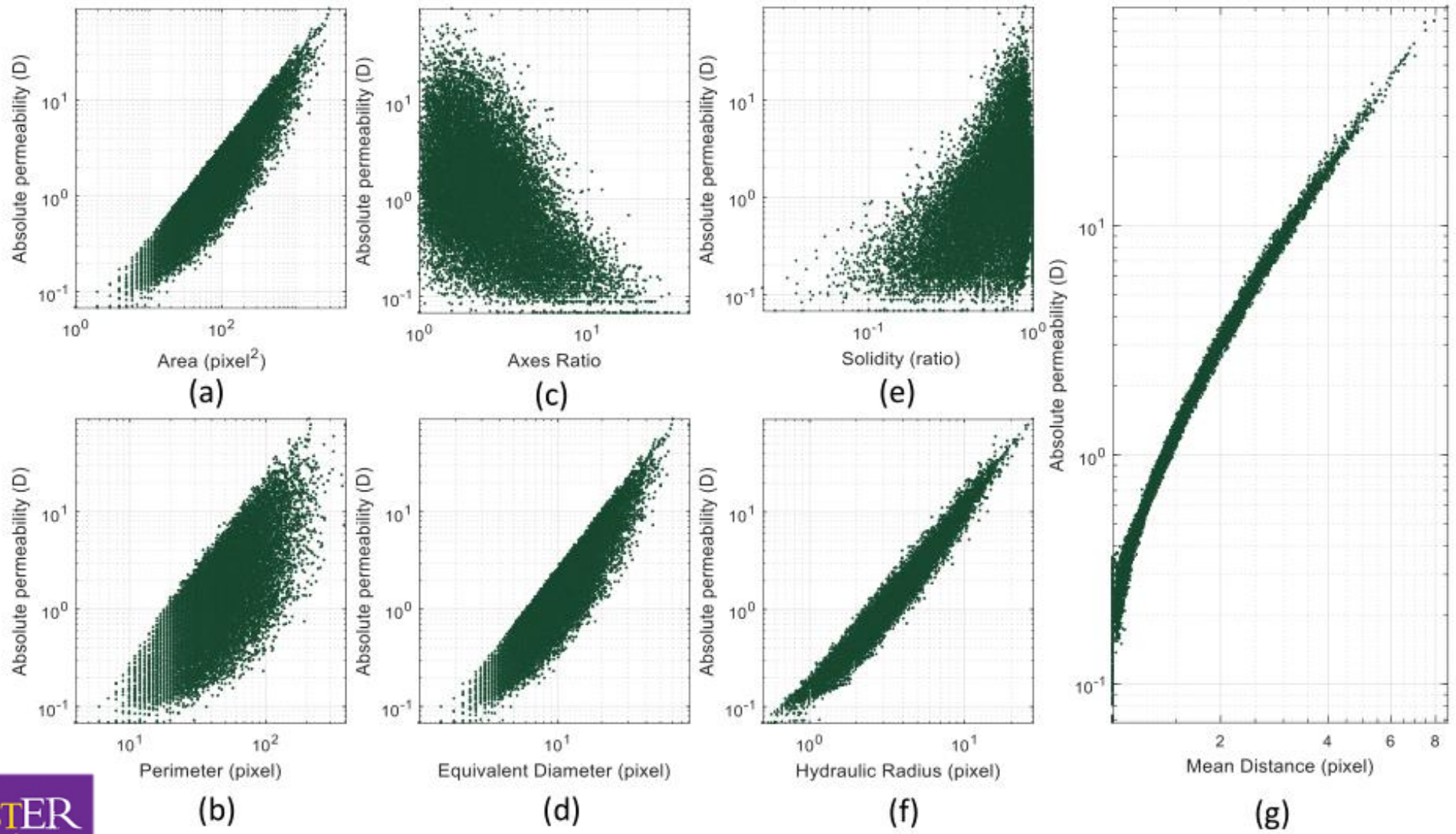
Features statistics



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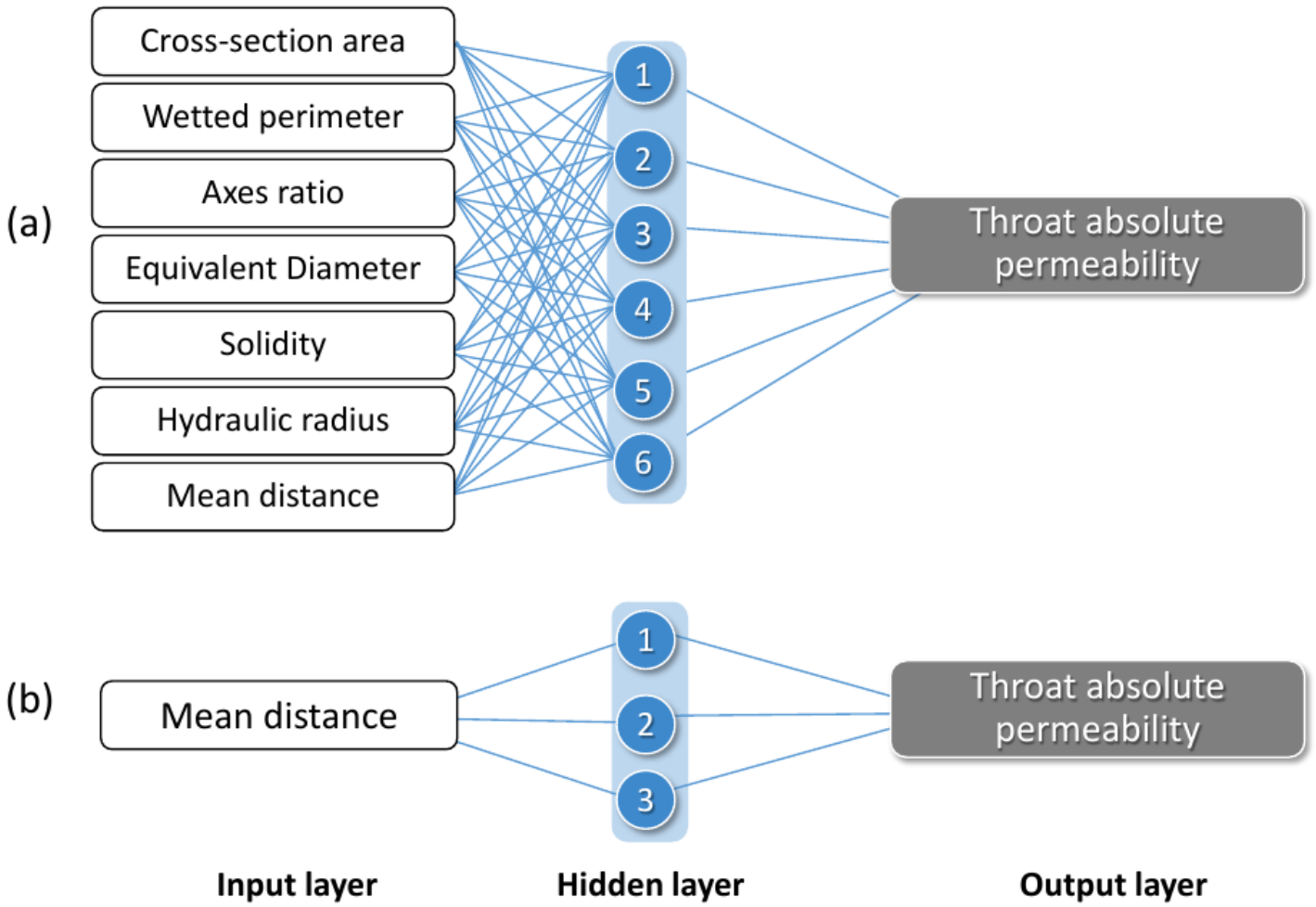
ANN structure



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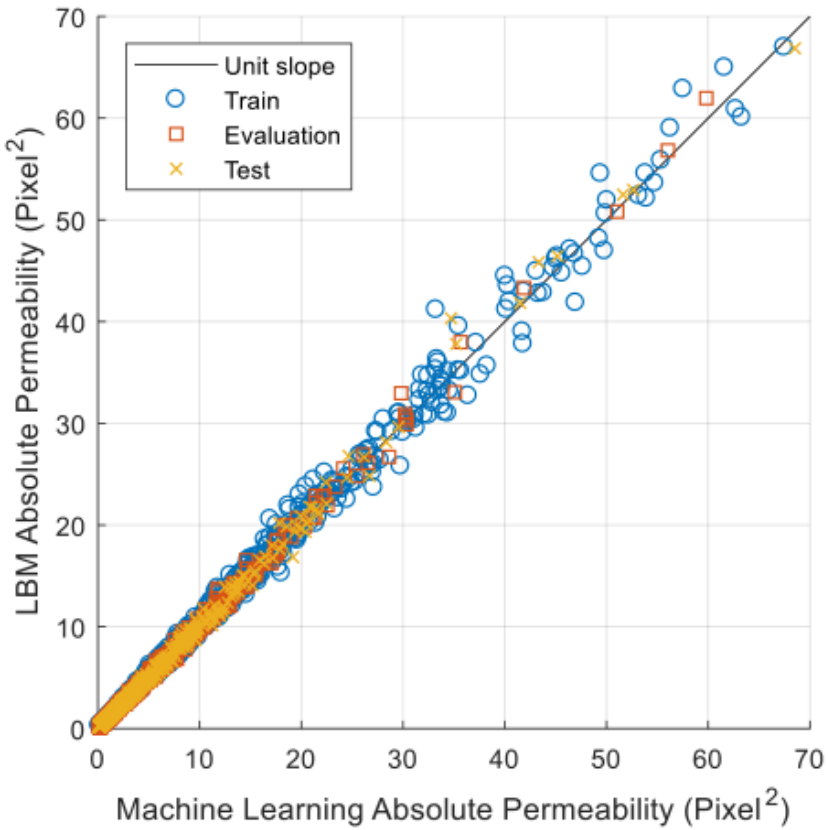
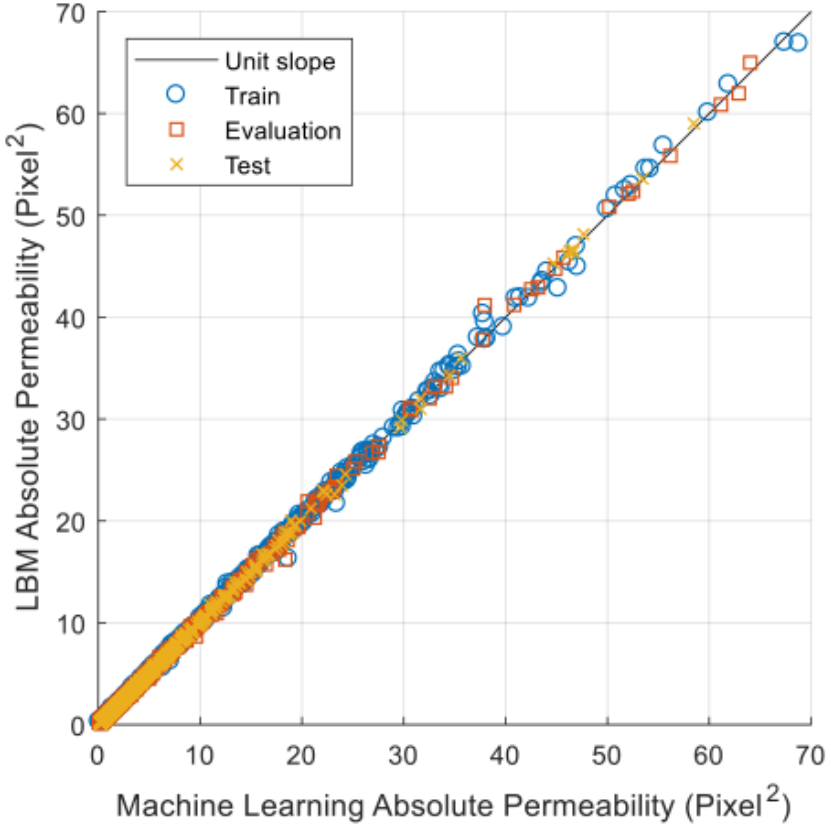


(a)



(b)

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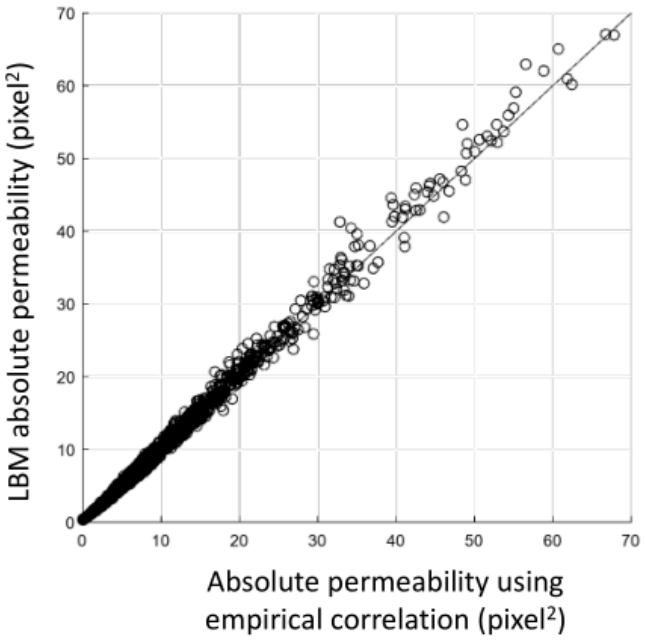
Empirical correlation



$$k_{throat} = 1.342\bar{D}^2 - 0.913\bar{D} - 0.381$$

Model constants	Mean value	Lower boundary	Upper boundary
a	1.342	1.338	1.345
b	−0.9127	−0.9376	−0.8878
c	−0.3814	−0.4131	−0.3498

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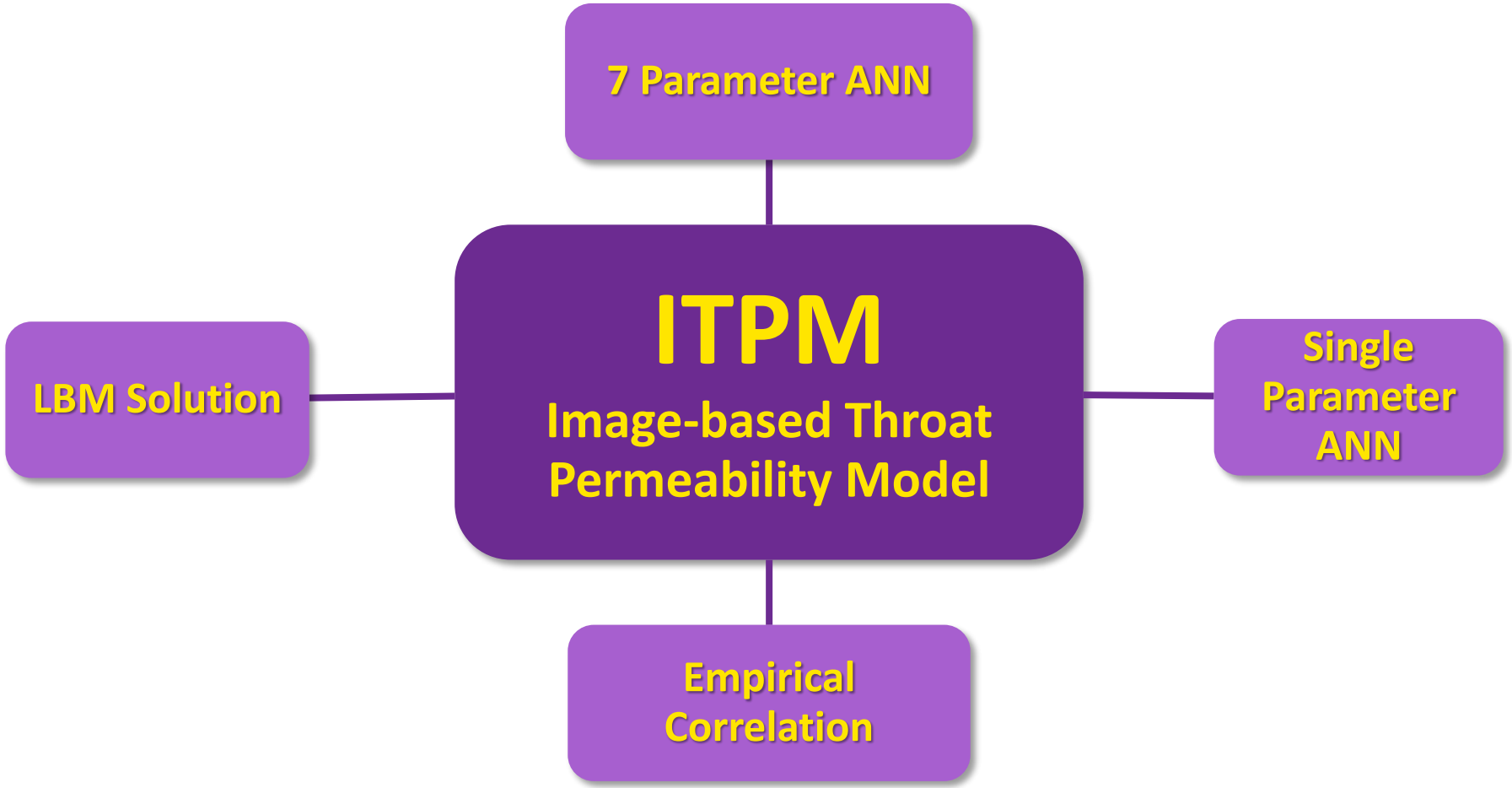
Image-based Throat Permeability Model

GitHub https://github.com/ArashRabbani/ITPM



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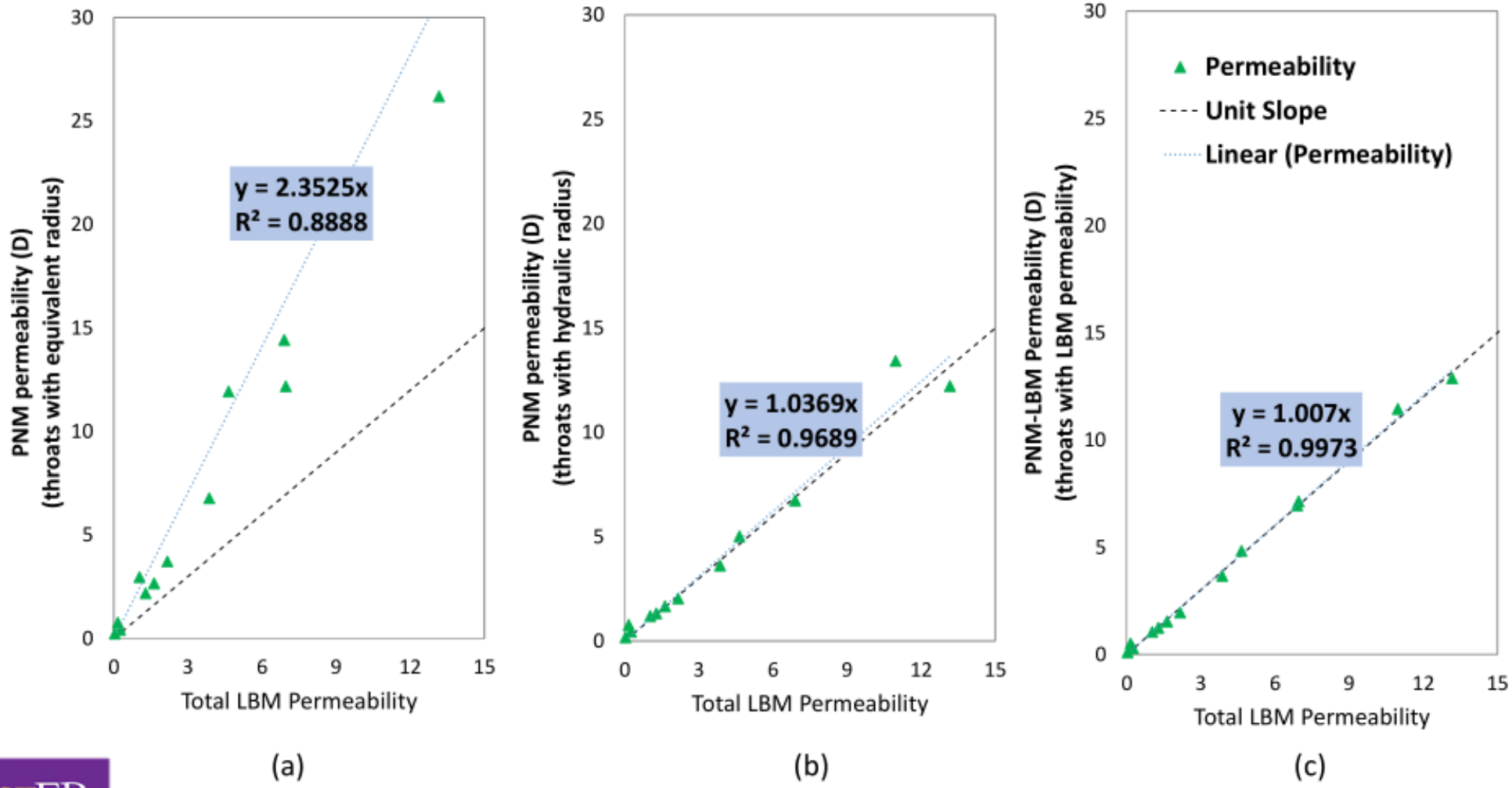
Permeability comparison



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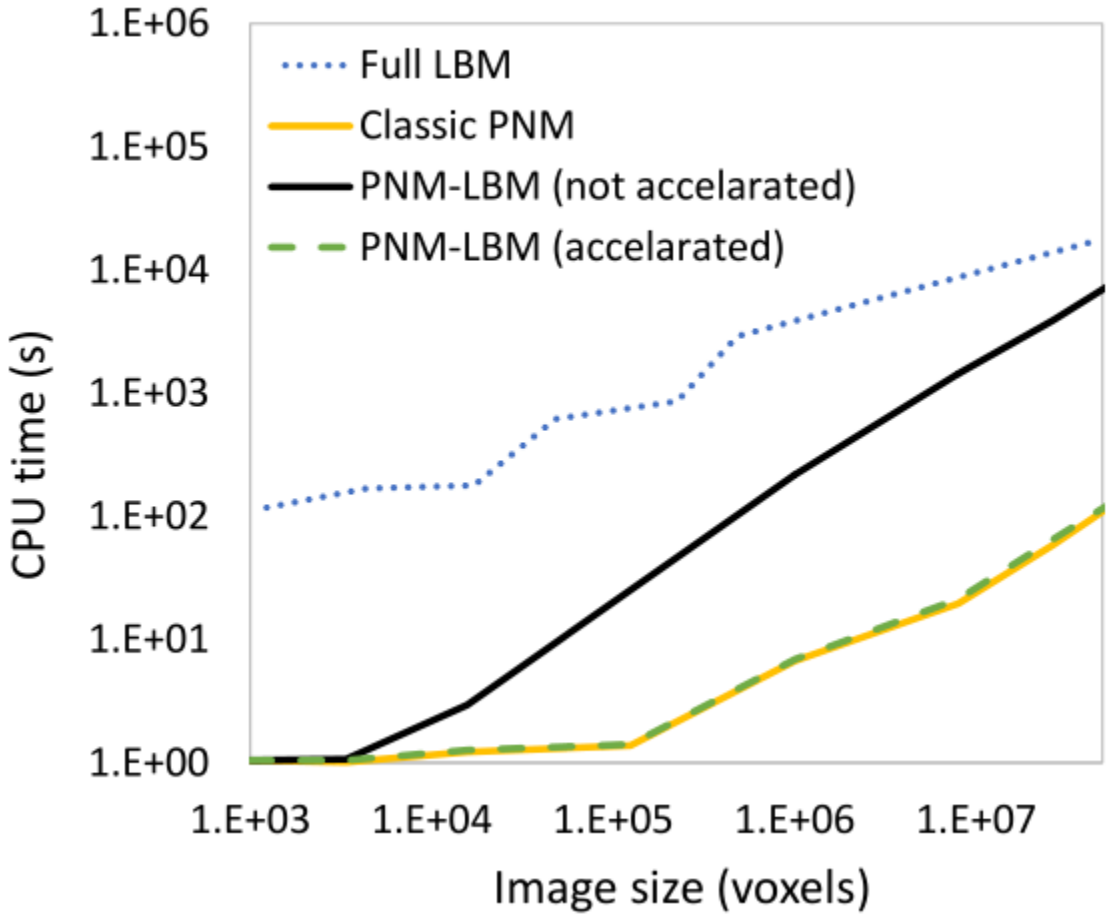
Computational costs



Thanks for your attention

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