Wavefront shaping for depth-enhanced OCT imaging

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Optical coherence tomography

- 3D imaging
- Sub-surface imaging
- Biomedical applications
  - Dermatology
  - Ophthalmology
  - Cardiology
  - ....

Human fingertip

Metallic tool

OCT calibration target

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OCT in a nutshell
OCT imaging

Limited penetration depth due to scattering

OCT scan at human nailfold region. (i) epidermis; (ii) dermis; (iii) cuticle; (iv) nail plate; (v) nail matrix; (vi) nail bed
OCT design

- Spatial light modulator (SLM) for beam shaping
- Independent shaping at reference and sample beam

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Wavefront shaping

SLM  Incident beam  detector  detector

Intensity vs. # iteration

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Iterative wavefront shaping

- Apply phase pattern to SLM
- Acquire OCT signal
- Optimize phase pattern to maximize signal

**Pros**
- Experimentally robust

**Cons**
- Very slow

Iterative

For each wavefront segment
- Apply different test-phases
- Choose value resulting in strongest signal

Genetic

- Create random phase patterns
- Rank according to resulting signal
- Create new from best-ranked patterns
- Repeat
Reflection matrix approaches

- Propagation is linear
- Matrix acquisition: apply one mode after another and get OCT signal

\[ E_{\text{det}} = T_{mn} A_n \]

\[ E_{\text{det}} = R_{mn} A_n \]
Reflection matrix approach

- Point-like enhancement
- Wide-target enhancement
- Depth-scan enhancement
  - One matrix acquisition per depth-scan
- B-scan enhancement

(a) Conventional OCT scan at chicken tissue.  
(b) Optimized scan.  
(c) Scan with commercial OCT system.  
(d) Depth-profiles of (a) and (b).

Kanngießer, J.; Roth, B. (2021): Reflection matrix approach for optical coherence tomography imaging, Physical Review Applied (under review)
Conclusion

• Double interferometer design
  • Easy implementation to existing OCT devices

• Iterative wavefront shaping
  • OCT signal enhancement demonstrated

• Reflection matrix approaches
  • Superior acquisition speed to iterative wavefront shaping
  • Improved algorithms compared to previous work
  • Application to OCT imaging demonstrated

• System too slow for clinical evaluation due to technical constraints
Future work
List of Publications

1. Kanngiesser, J; Rahlves, M.; Roth, B. (2019): *Double interferometer design for independent wavefront manipulation in spectral domain optical coherence tomography*, Scientific Reports 9, art.no. 14651
   DOI: 10.1038/s41598-019-50996-2

   DOI: 10.1364/OL.44.001347

   ISSN 1614-8436, https://www.dgao-proceedings.de/download/120/120_a2.pdf

   ISBN: 978-952-68553-6-3
List of Publications (cont.)


Thank You for Your attention

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