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Review:

Computational methods in super-resolution microscopy

Key words: Super-resolution microscopy; Deconvolution; Computational methods

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Motivation

- The development of novel computational methods would greatly benefit the applications of super-resolution optical microscopy.
- To comprehensively analyze and discuss the advantages, drawbacks, and scope of applications of commonly used super-resolution methods.

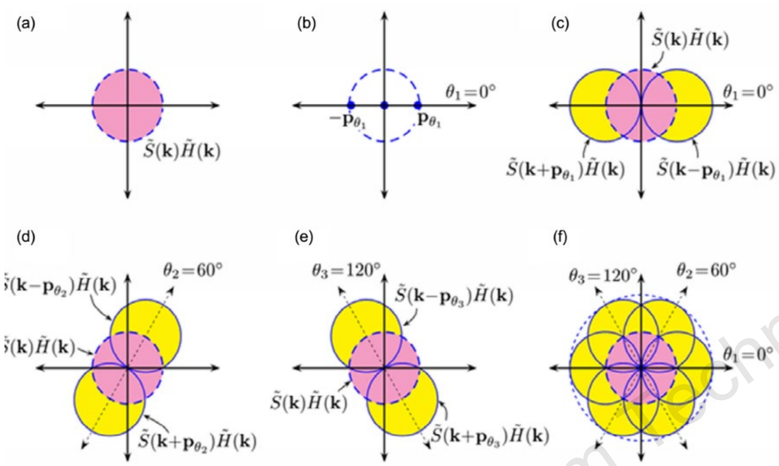
Contribution

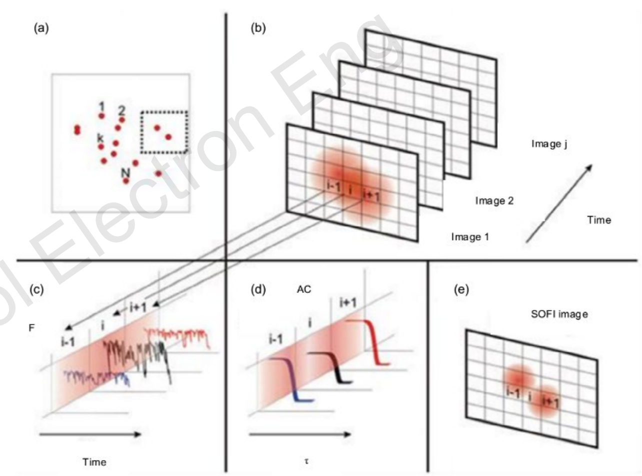
1. To provide the general concepts and developments of super-resolution optical microscopy

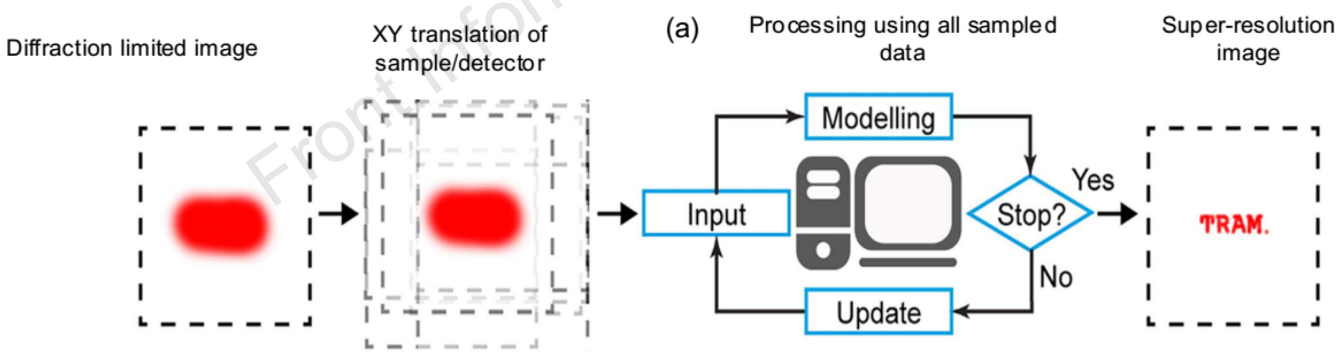
2. To provide state-of-the-art progress of different types of super-resolution microscopy, including:

Deconvolution microscopy, polarization-based super-resolution microscopy, structured illumination microscopy, image scanning microscopy, super-resolution optical fluctuation imaging microscopy, single-molecule localization microscopy, Bayesian super-resolution microscopy, stimulated emission depletion microscopy, translation microscopy

Illustrative discussion







Comprehensive explanation and comparison of the different computational methods of various super-resolution microscopy techniques

- Comparison of different super-resolution microscopy techniques:

Super-resolution techniques	Principle	Typical resolution (nm)	References
Deconvolution microscopy	To calculate the inverse problem of convolution, because imaging is a convolution process	150	Biggs, 2010; Falk and Lauf, 2001; Jansson, 2014
Sparse deconvolution microscopy (FPM, SPoD, SDOM)	Improve the resolution with sparse deconvolution, and determine the fluorescence dipole orientation with modulation fitting	75	Axelrod, 1989; Hafi *et al.*, 2014; Zhanghao *et al.*, 2016
SIM	Use Moiré interference (differential frequency) to bring the high frequency feature to low frequency	100	Gustafsson *et al.*, 2008; Li *et al.*, 2015; Yang *et al.*, 2016b; Yu *et al.*, 2016
ISM	Spatial deconvolution of the obtained confocal PSF	150	Müller and Enderlein, 2010; Sheppard *et al.*, 2013; Yang *et al.*, 2016b; Yu *et al.*, 2016
SOFI	Calculate the high-order correlation of the random blinking statistics of the emitters	75	Dertinger *et al.*, 2009; Geissbuehler *et al.*, 2012
SMLM	Localize the position of each single molecule for super-resolution imaging	10–20	Betzig *et al.*, 2006; Hess *et al.*, 2006; Rust *et al.*, 2006; Yang *et al.*, 2016b; Yu *et al.*, 2016
3B	Calculate the Bayesian statistics of the random blinking emitters	50	Cox *et al.*, 2012
STED	Employ stimulated emission to shrink the PSF down to subdiffraction size; the subsequent deconvolution process further enhances the resolution and contrast	20–30	Schoonderwoert *et al.*, 2013
TRAM	Achieves a high-resolution image from multiple deconvolved low-resolution translation images	~50	Qiu *et al.*, 2016

Conclusions

- The improvement of computational methods can significantly enhance the spatial resolution, imaging speed, image accuracy, and achieve faster image processing in super-resolution microscopy.

- The currently developed super-resolution techniques may also benefit the computational image processing techniques in their respective applications, when the image data shares a similar digital nature through current or modified instrumentation.