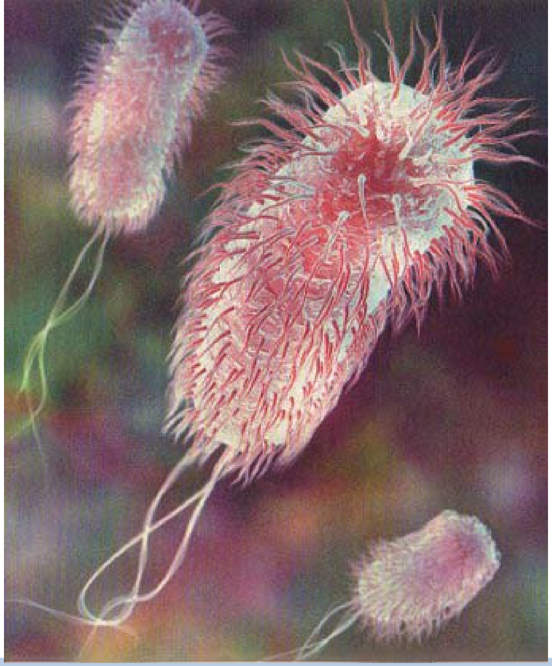
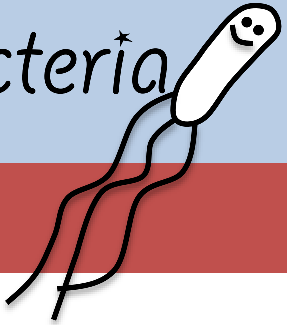


3D Rotational Diffusion of an E-coli Bacteria



Mohammad Charsooghi

Under Supervision of:

Dr Khalesi & Dr Golestanian

Institute for Advanced Studies in Basic Sciences, Zanjan, Iran. Nov/11/2009

Rotational Diffusion of an E-coli Bacteria

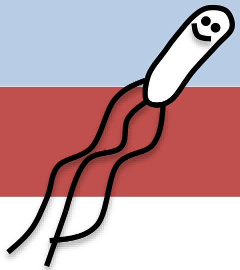


Table of contents

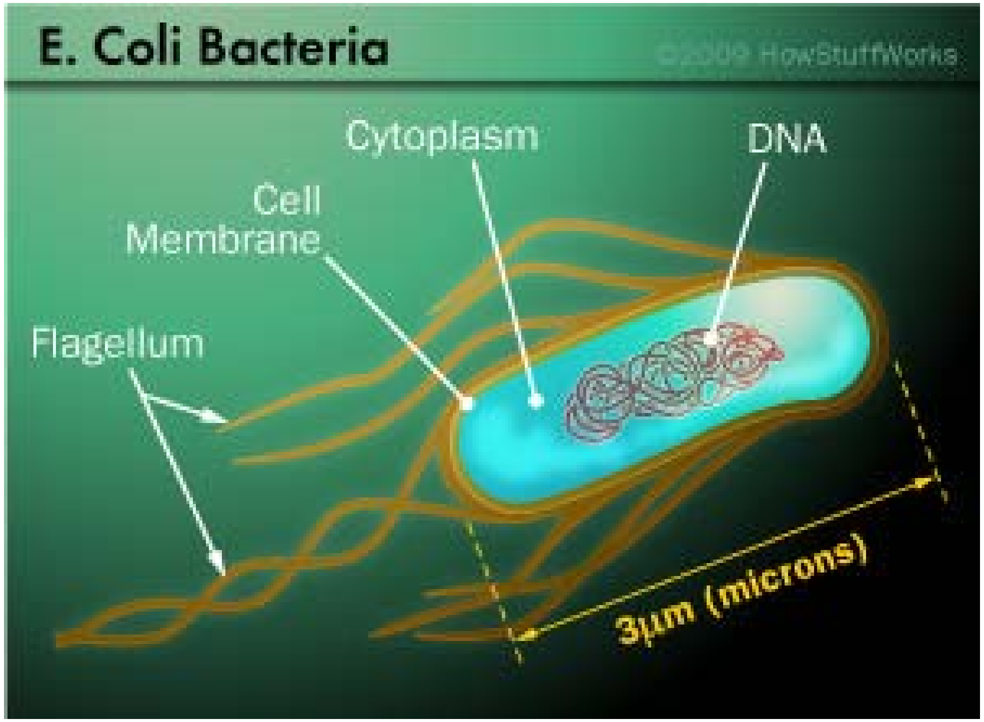
What is an E-coli Bacteria

Biological points of view

What is E-Coli?

E-coli is a bacteria which normally lives inside your intestines.

E-coli is a prokaryotic cell.



What is inside E-Coli?

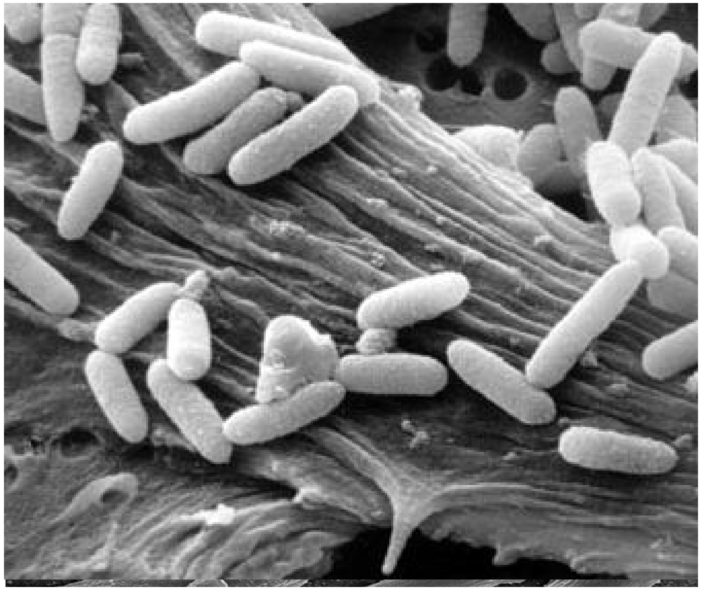
- DNA
- Cytoplasm
- Cell Membrane
- Flagellum

What is an E-coli Bacteria

Physical points of view

Why E-Coli Bacteria is important?

- grown easily and rapidly (20 min)
- its genetics are simple and easily-manipulated
- long history of laboratory culture
- Safty



Physical properties of an E-coli:

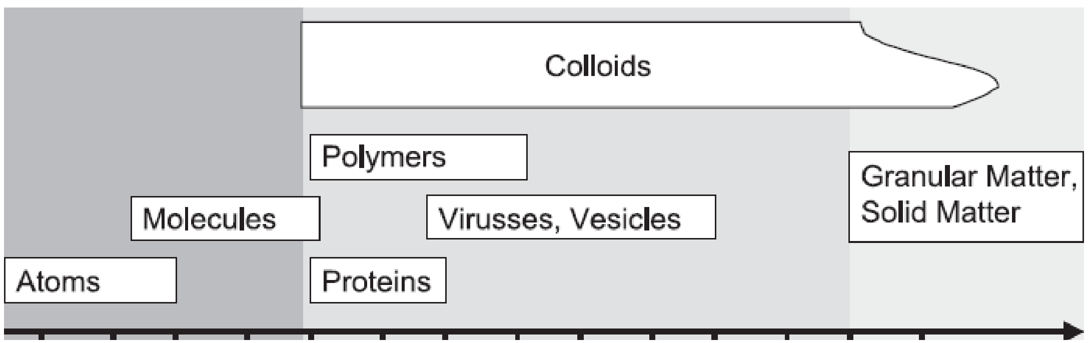
- rod-shaped
- about 2 μm long and 0.5 μm in diameter.
- cell volume of 0.6 - 0.7 μm^3.
- Its DNA is more than 300 times longer. So, the DNA is tightly coiled and twisted to fit inside.
- Optimal growth of *E. coli* occurs at 37°C

Colloidal Particle

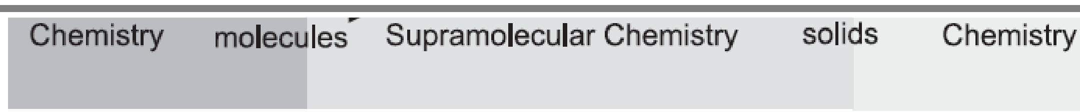
What is a Colloid ?

What is a colloidal particle?

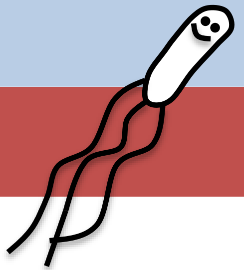
Have a length scale in at least one direction, about tens of nm to tens of um



Particle type	Suspending medium	Name	Examples
solid	liquid	suspension / sol	paint, ink
liquid	liquid	emulsion	fat in water, salad dressing
gas	liquid	foam	whipped cream
solid/liquid	gas	aerosol	smoke / clouds,



Why Colloids are Important?



Why the colloids are important?

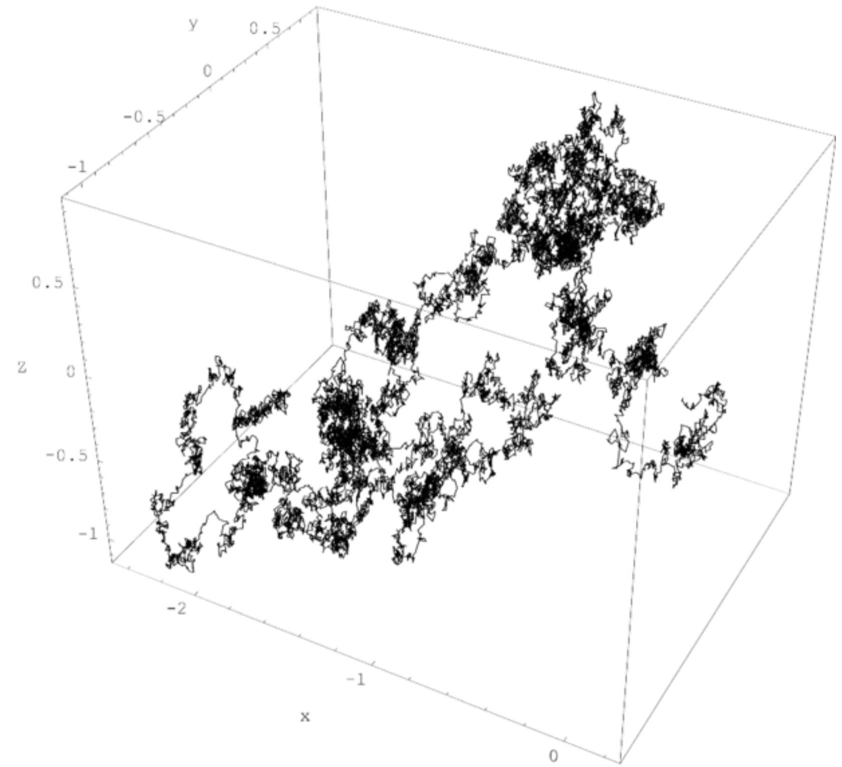
- The size of the particles are sufficiently large to observe via usual microscopy techniques
- The size of the is as tiny as enough to have a Brownian motion.
- So they can transfer energy and cause physical system to reach equilibrium.
- Like many physical system have different kinds of phases.
- Can consider as a good model to interpret many kinds of physical situations.

A brief physical concept of Random Walk and Diffusion

Diffusion is the movement of particles from an area of high concentration to an area of low concentration until it is evenly distributed.

In cell biology, diffusion is a main form of transport for necessary materials such as amino acids within cells.

Diffusion of a fluid (anything that moves like a liquid) through a partially permeable membrane is classified as **osmosis**.



Translational and Rotational Diffusion

Diffusion from a Mathematical Point

Calculate Diffusion Coefficient Theory

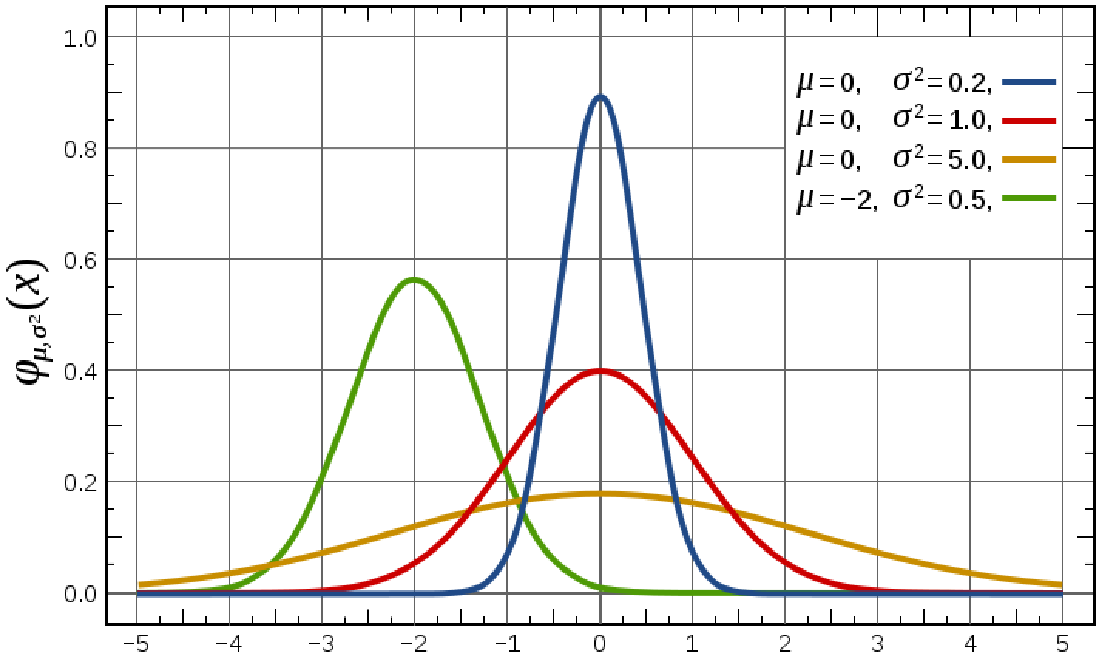
Einstein's Eq. $$D = \frac{K_B T}{\gamma}$$

$$\gamma = 6\pi\eta r$$

Stokes' Eq. $$F = \gamma v$$

Reynolds' number $$\mathfrak{Re} = \frac{\rho V L}{\eta}$$

The relations to calculate Diffusion:

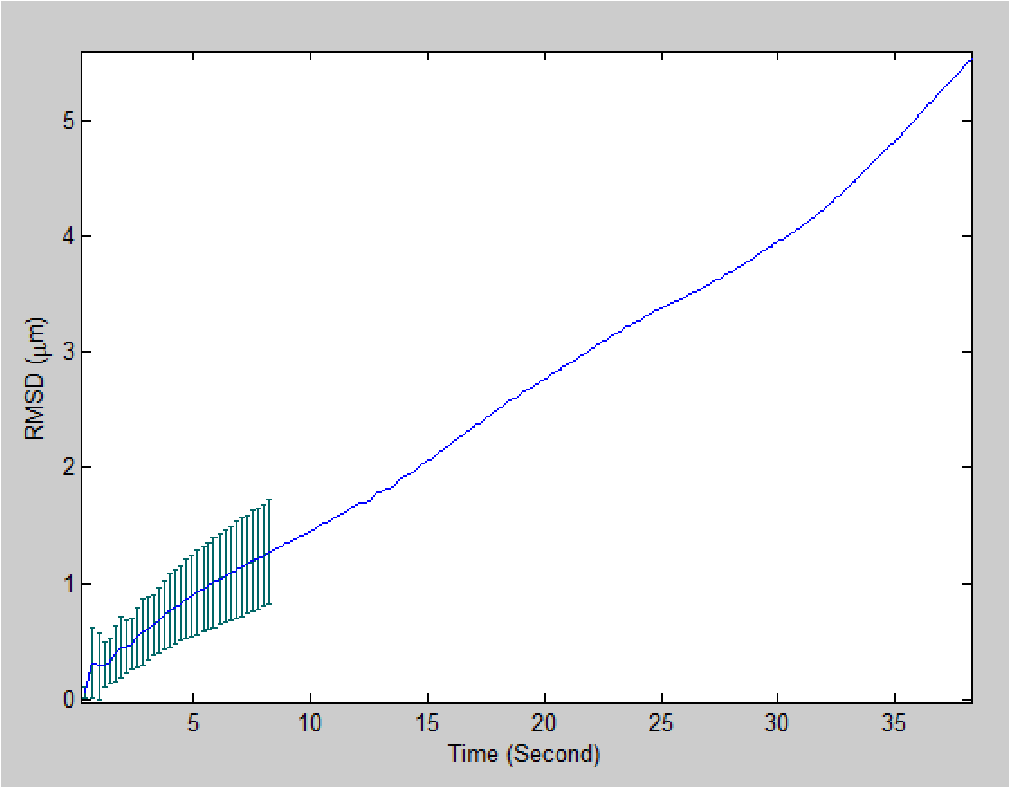


$$\Delta \begin{Bmatrix} x \\ y \\ z \end{Bmatrix}(t) = \begin{Bmatrix} x \\ y \\ z \end{Bmatrix}(t+\tau) - \begin{Bmatrix} x \\ y \\ z \end{Bmatrix}(\tau)$$

$$\langle(\Delta x)^2\rangle - (\langle\Delta x\rangle)^2 = 2Dt$$

MATLAB Program to Calculate Diffusion

First: Time Average
Fitting with weight



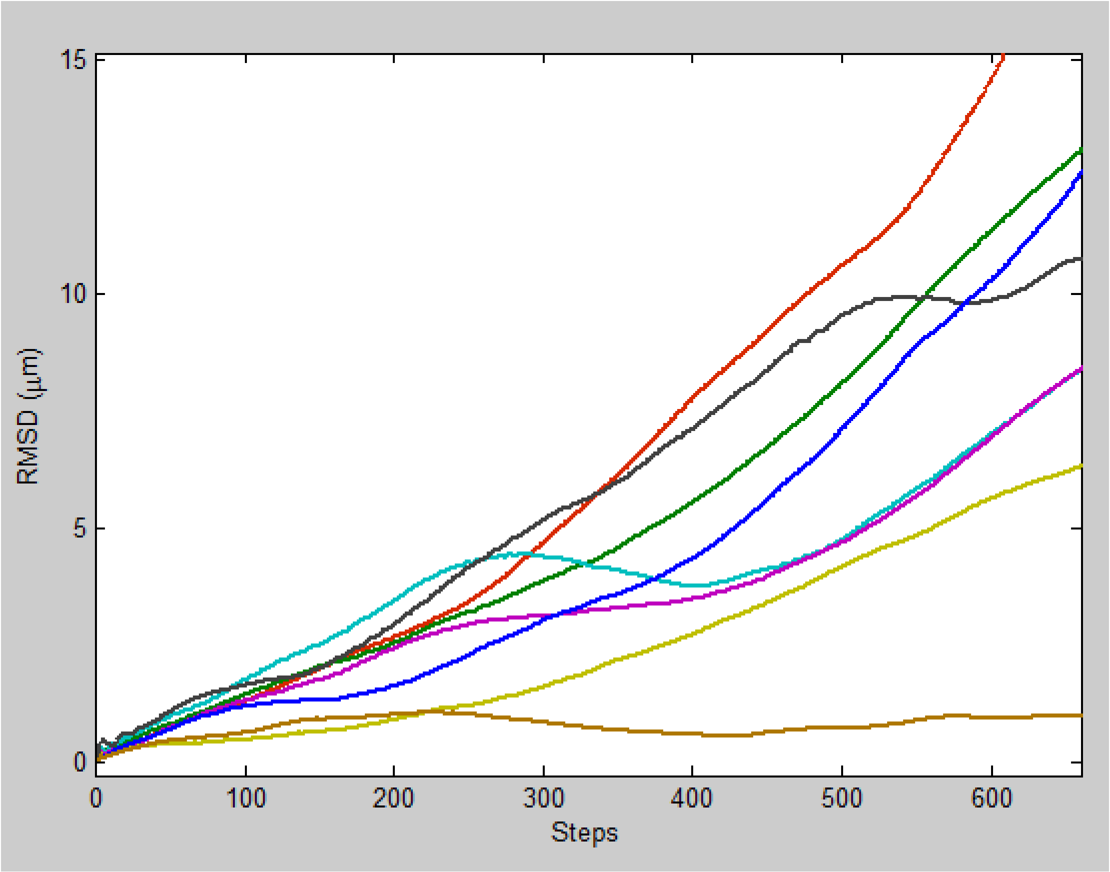
$$\Delta \begin{Bmatrix} x \\ y \\ z \end{Bmatrix} (t) = \begin{Bmatrix} x \\ y \\ z \end{Bmatrix} (t+\tau) - \begin{Bmatrix} x \\ y \\ z \end{Bmatrix} (\tau)$$

$$\langle (\Delta x)^2 \rangle - (\langle \Delta x \rangle)^2 = 2Dt$$

$$\Delta\theta(t) = \theta(t+\tau) - \theta(\tau)$$

MATLAB Program to Calculate Diffusion

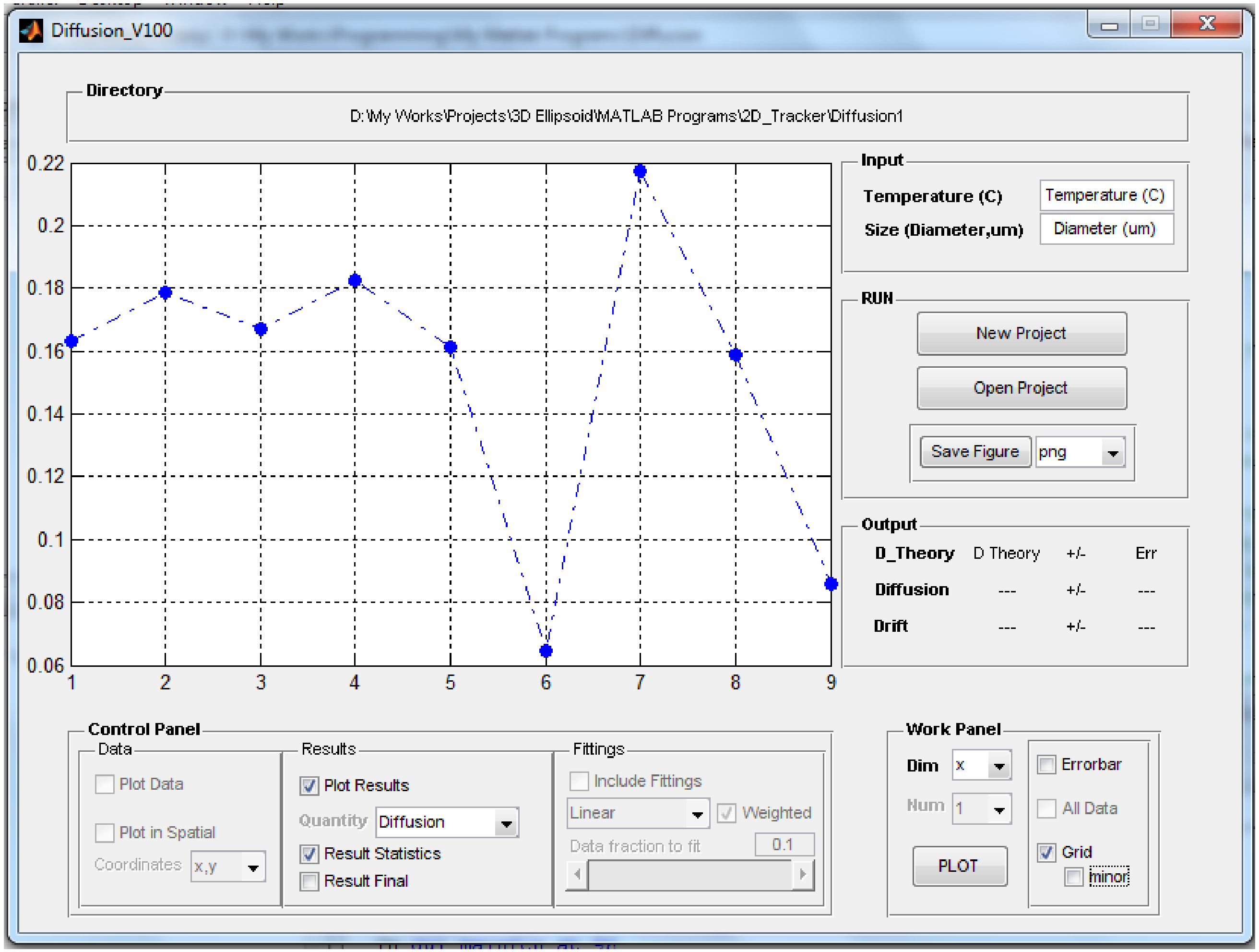
Second: Ensemble average to estimate error



Translational and Rotational Diffusion

MATLAB Program to Calculate Diffusion

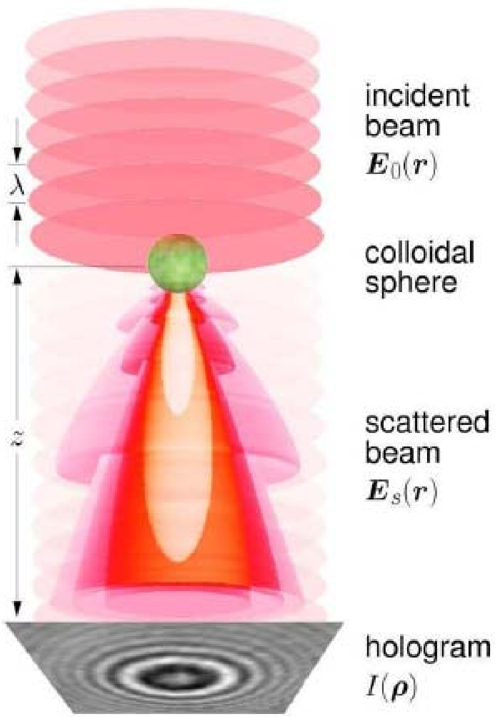
A Graphical User Interface (GUI) Version of Our Diffusion Program

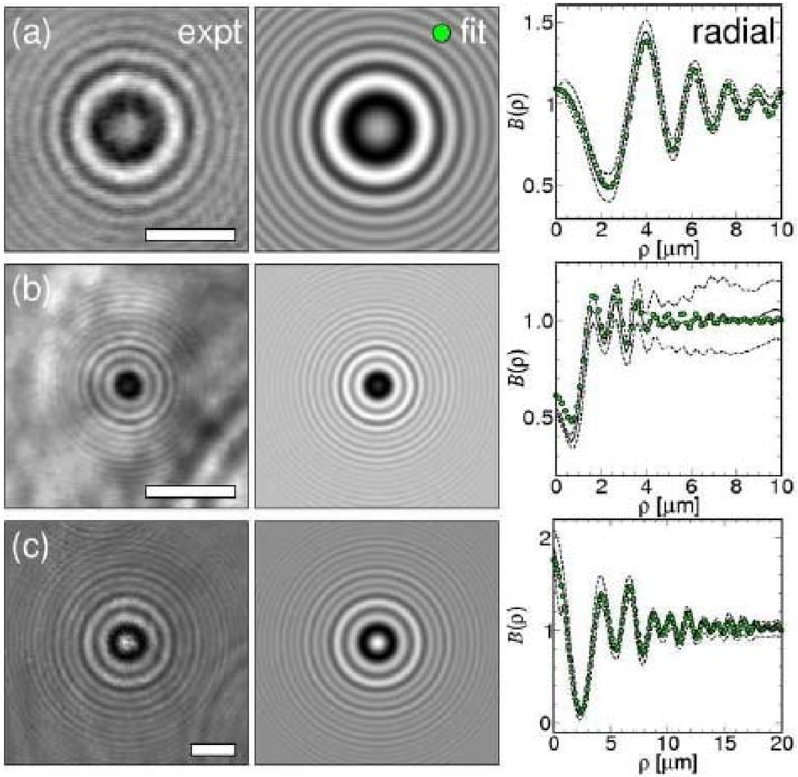


Other Works on 3D Particle Tracking

Characterizing and tracking single colloidal particles with video holographic microscopy

Sang-Hyuk Lee,[1] Yohai Roichman,[1] Gi-Ra Yi,[2] Shin-Hyun Kim,[3] Seung-Man Yang,[3] Alfons van Blaaderen,[4] Peter van Oostrum,[4] and David G. Grier[1]



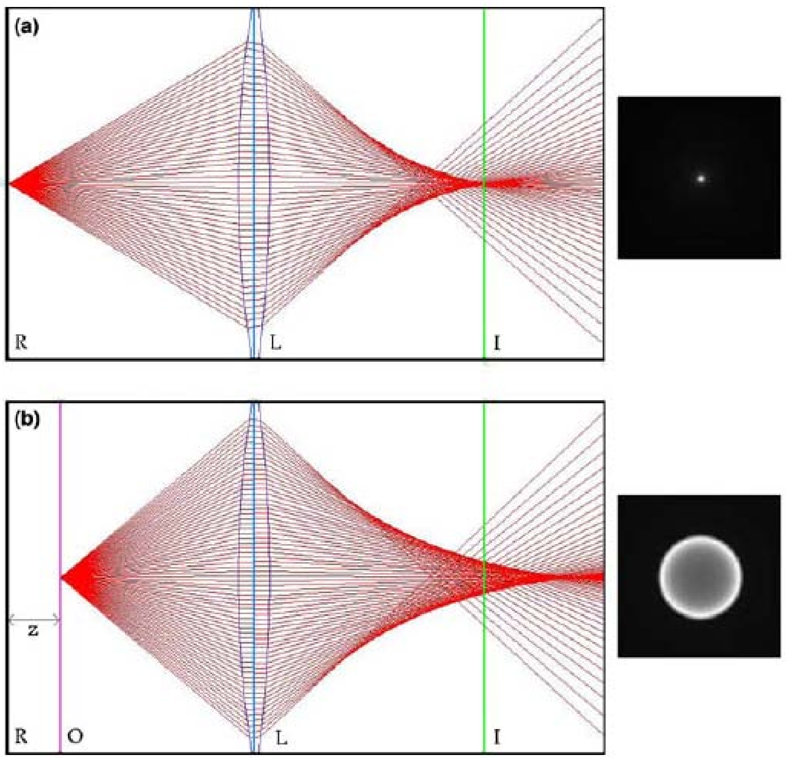


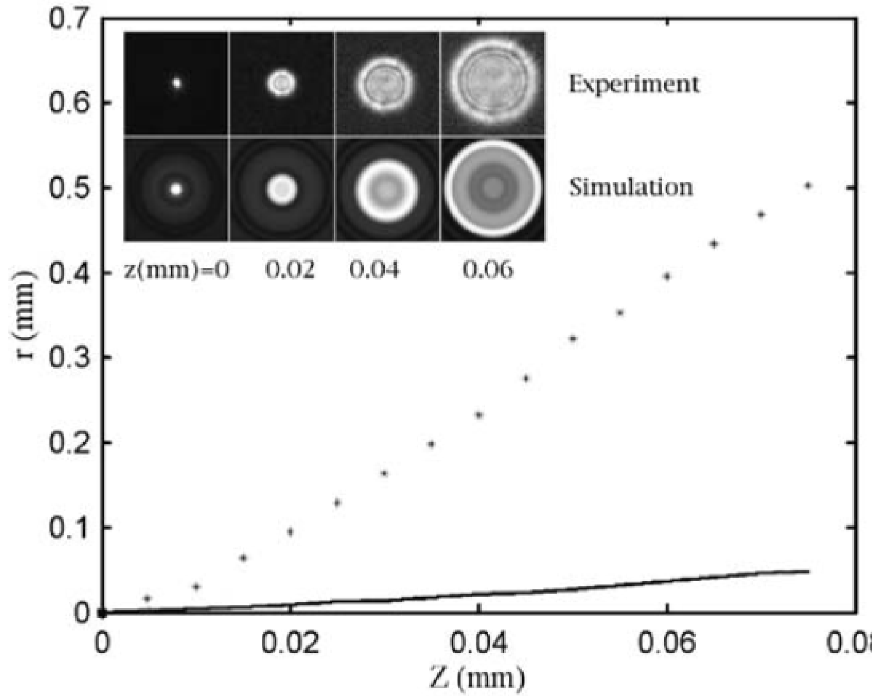
3D Particle Tracking of an Ellipsoid

Other Works on 3D Particle Tracking

Mingming Wu · John W. Roberts · Mark Buckley

Three-dimensional fluorescent particle tracking at micron-scale using a single camera



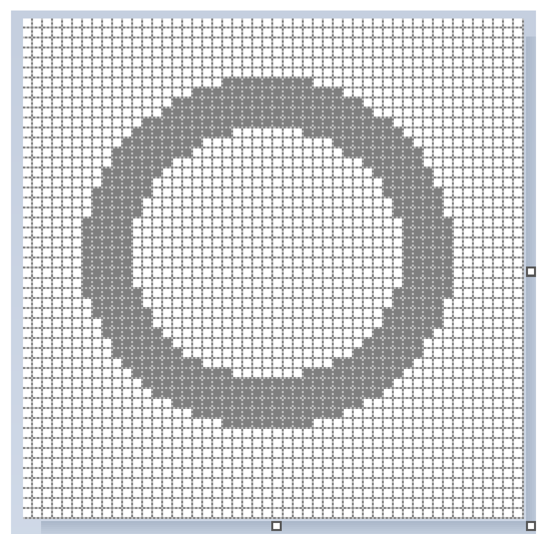


3D Particle Tracking of an Ellipsoid

Our Approach in 2D

How we determine the position of a colloidal particle

Subpixel resolution



Controlling Piezo Electric using MATLAB

General Command Set (GCS) System

ONL 1
SVO A1
MOV A30.450
POS? A

Some important MATLAB command to control PI

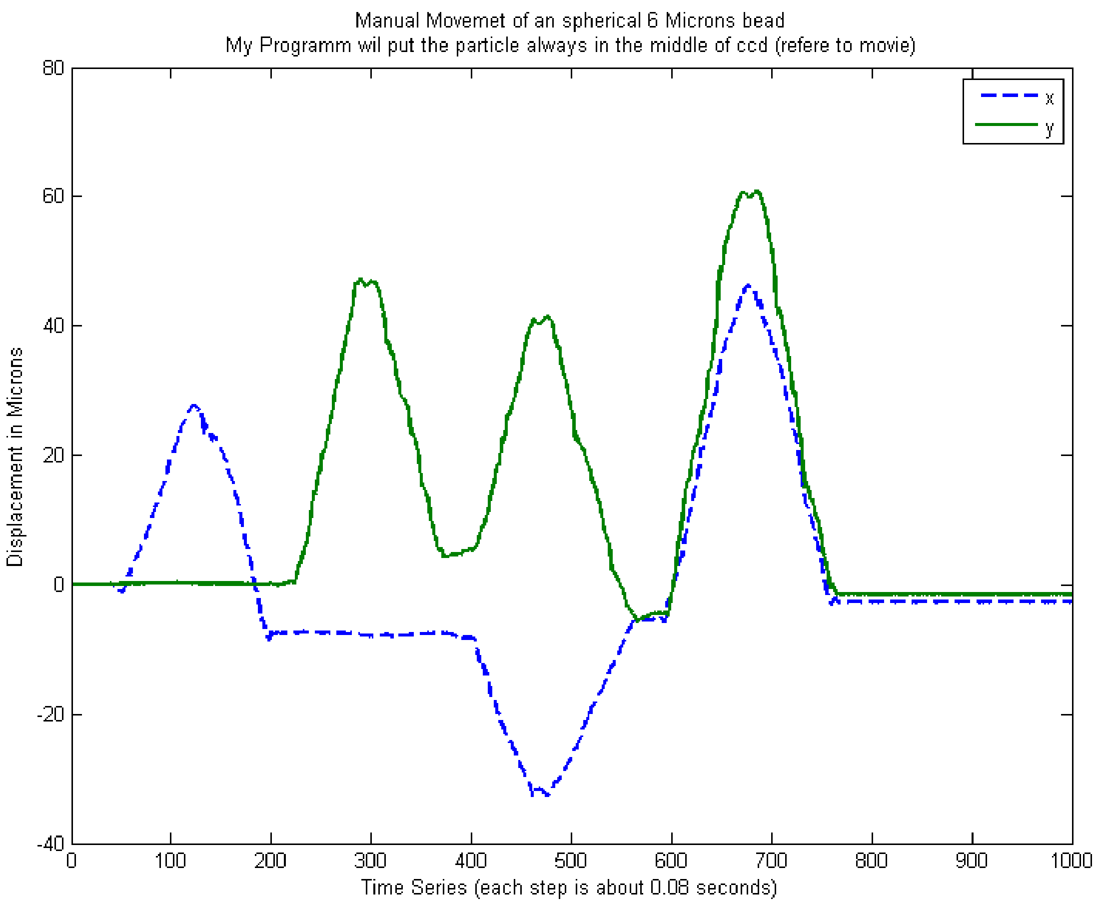
```
ID = serial('COM1','BaudRate',57600);
fopen(ID)

fprintf(ID,'ONL 1'); pause(0.5)

fprintf(ID,'SVO A1 B1'); pause(0.5)
fprintf(ID,'DCO A1 B1'); pause(0.5)
fprintf(ID,'VCO A1 B1'); pause(0.5)

fprintf(ID,'VEL A50 B50'); pause(0.5)
fprintf(ID,'MOV A100.000 B100.000'); pause(0.5)
```

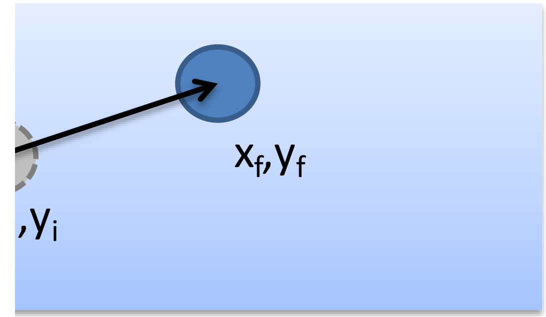
Safety Notes

3D Particle Tracking of an Ellipsoid

2D Tracker and Results

The mechanism of our 2D tracker

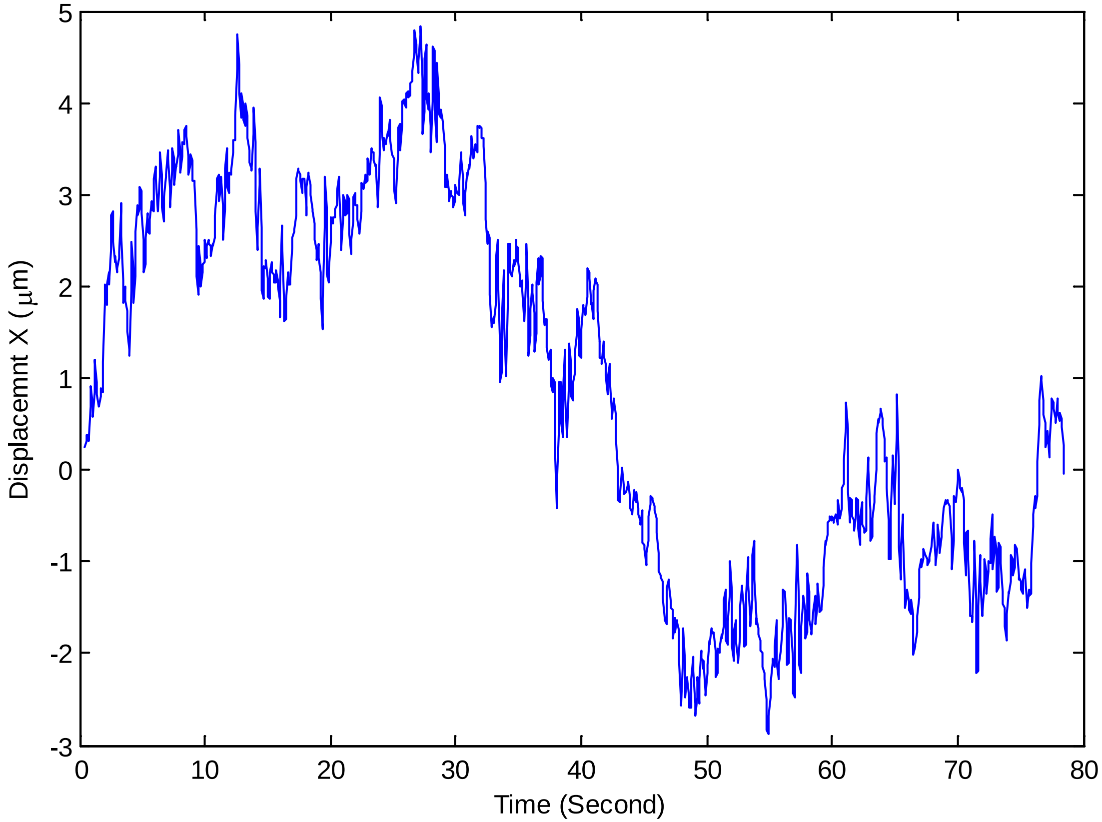




2D Tracker and Results

The results for the brownian motion of an ecoli

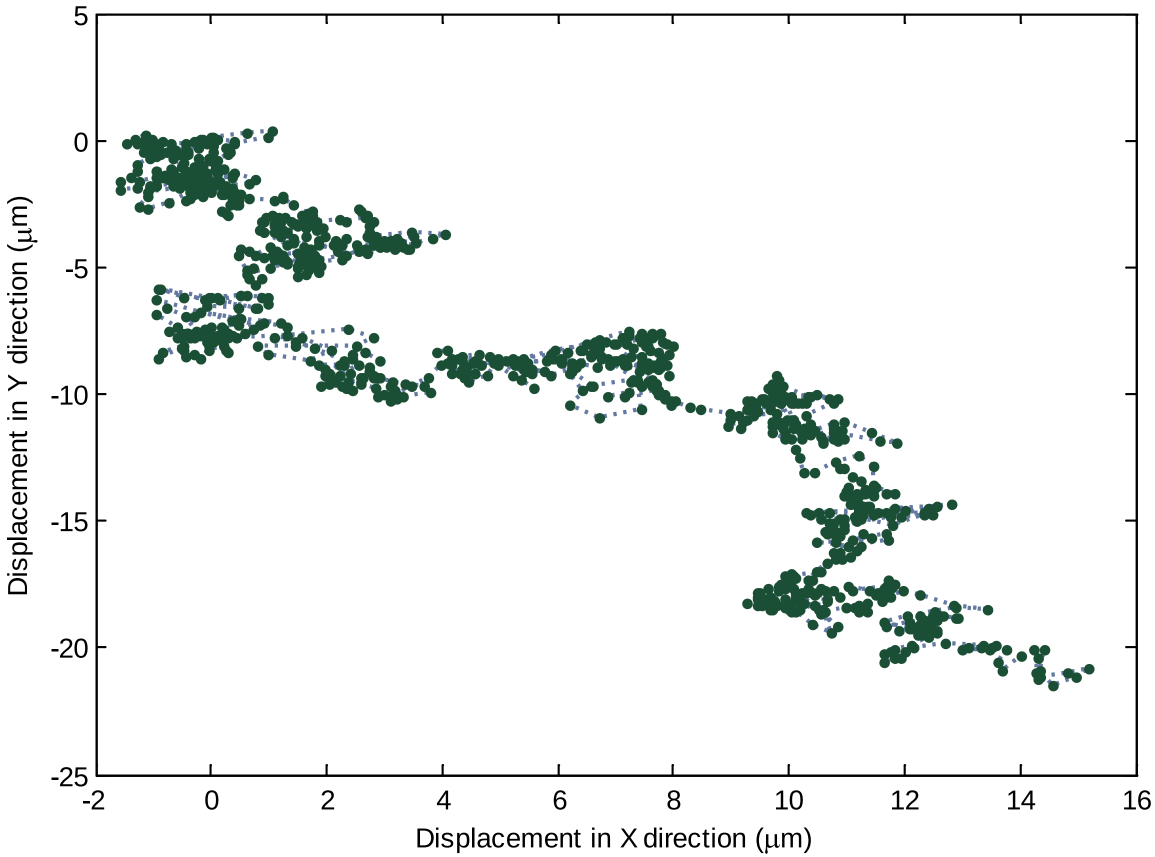
Spherical Polystyrene Bead
2.1 microns in Diameter
Temperature = 20 °C
Density$_{water}$ = 1000 kg/m^3
Density$_{bead}$ = 1050 kg/m^3
Viscosity$_{water}$ = 10^{-3} Pa.S



3D Particle Tracking of an Ellipsoid

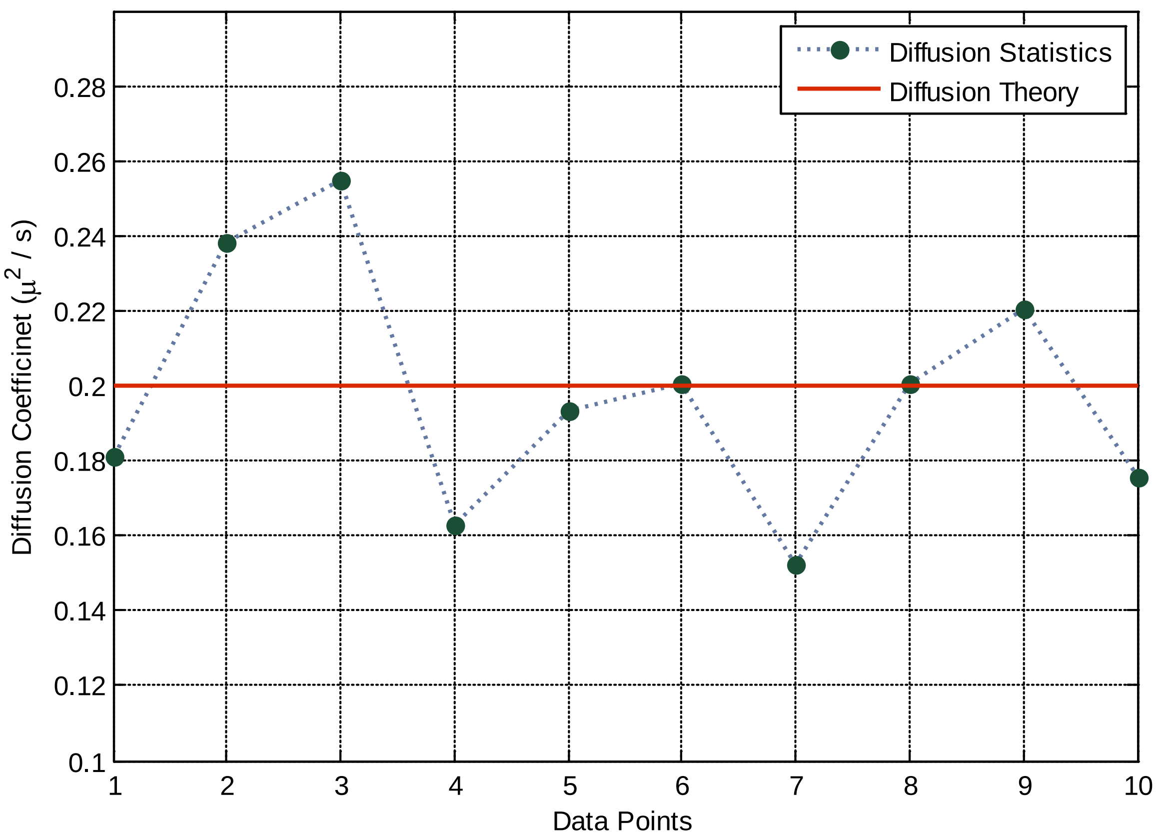
2D Tracker and Results

The result in x-y plane



2D Tracker and Results

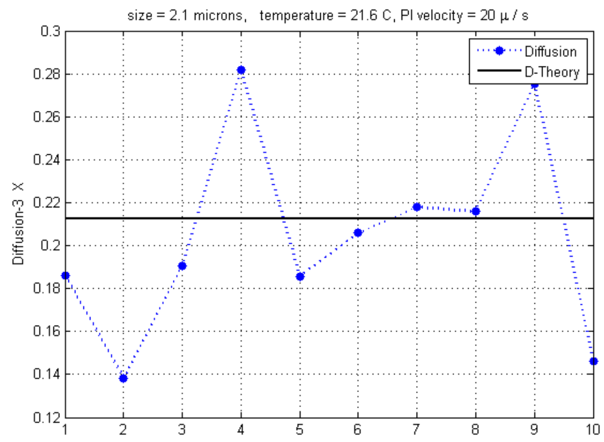
Diffusion Statistics

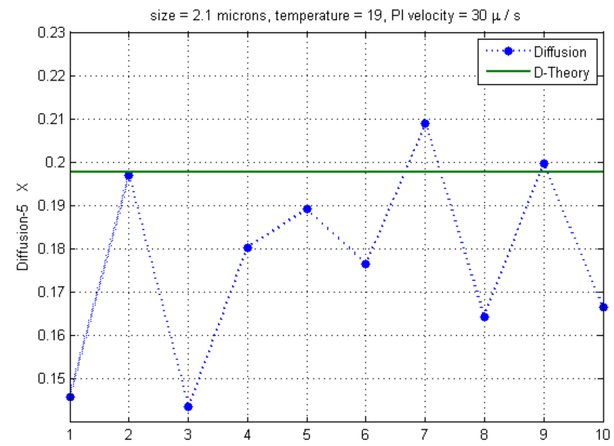


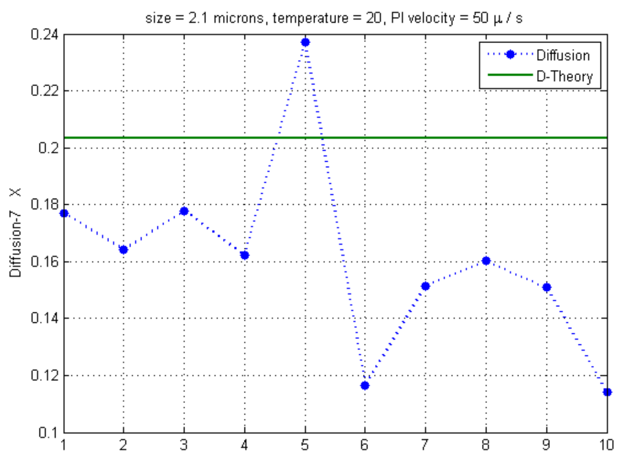
3D Particle Tracking of an Ellipsoid

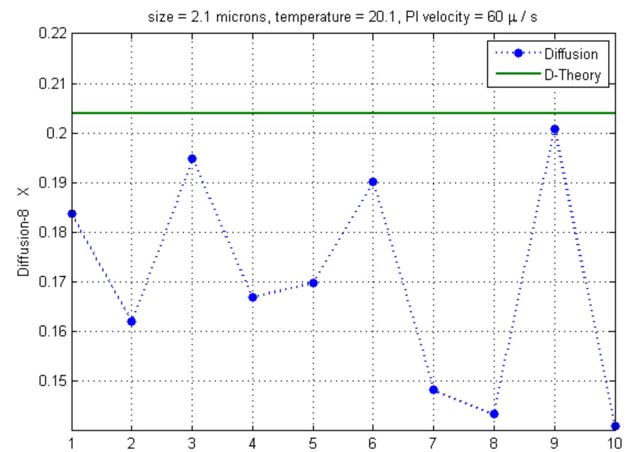
2D Tracker and Results

The effect of the velocity of PI on Diffusion Coefficients:





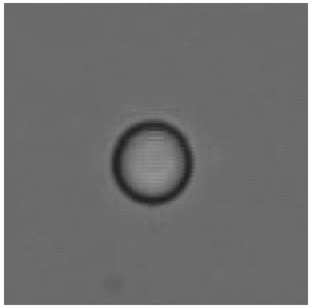


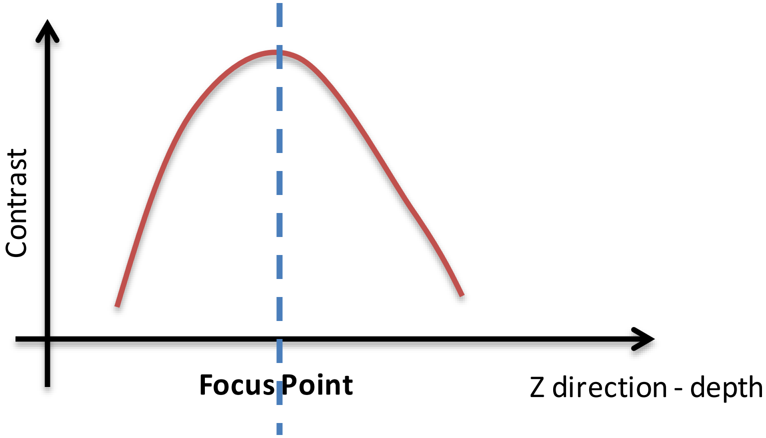


Two Candidate Approach for 3D

Candidate 1

Calibration of contrast respect to focus position





Candidate 2

Auto contrast detection

Conclusion: The (Dis) Advantages of this Method

Advantages:

- We will have the position of particle online
- There is no limit in the range of tracking, the only limit is you PI range
- In comparison with other methods, it doesn’t need any heavy data and image analysis
- The model is very simple

Disadvantages:

- The effect of PI motion on the velocity of particle
- The piezo stage is not inexpensive

Thank you