Pizza3 - WORKSHOP - PostTreatment - Part 1

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Synopsis

The workshop is organized into two interconnected parts to demonstrate how spatial and temporal information can be reconstructed from the dynamics of multi-particle systems, as utilized in Pizza3. The workshop focuses on managing large data files generated from MD-like simulations that contain atomistic information such as positions, velocities, forces, and more. Through specific post-treatment, these details are converted into meaningful time or spatial averages or fluctuating quantities.

Part 1: Temporal Information Extraction

Objective: To extract temporal information from large dump files (5-100 GB) generated by LAMMPS that are beyond the processing capacity of conventional computers.

Applied Physics: The section emphasizes simple physical concepts, aiming to illustrate how scalar quantities can be retrieved and plotted with low computational cost.

Key Learnings:

- Preprocessing of large files.
- Analysis of temporal evolution for selected particles.
- Study of solid obstacle dynamics (including position and movement, shape deformation, and moment of inertia analysis).

Part 2: Spatial Reconstruction and Field Analysis

Objective: Utilizing the results from Part 1, this section aims to reconstruct various fields (velocity, stresses) through the definitions of underlying physics and kernel interpolation.

Key Learnings:

- First description of fluid-solid interactions.
- Visualization techniques.
- Overview of possible extensions.

Overall, the workshop provides hands-on experience and detailed understanding of translating complex particle dynamics into meaningful physical insights, with an emphasis on efficient computational methodologies.

Description and dependencies

```
% WORKSHOP built on Billy production file (suspended particle in a fluid)
% This example takes the benefit of a Lagrangian description

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```

```
% MATLAB FILES included in this distribution (either from INRAE/MS or Pizza3
project)

% Main file
% ├─── example1.m

% Main features demonstrated
% ├─── lamdumpread2.m     ==> the Swiss knife for the manipulating HUGE
dump files (version 2 as it is the fork for Pizza3)
% ├─── buildVerletList.m  --> the basic tool for statistical physics, it
implement an efficient grid search method

% Other dependencies and future workshop extensions (from Pizza3)
% ├─── checkfiles.m
% ├─── forceHertzAB.m
% ├─── forceHertz.m
% ├─── forceLandshoff.m
% ├─── interp2SPH.m
% ├─── interp3SPH.m
% ├─── interp3SPHVerlet.m
% ├─── kernelSPH.m
% ├─── KE_t.m
% ├─── packing.m
% ├─── packing_WJbranch.m
% ├─── packSPH.m
% ├─── particle_flux.m
% ├─── partitionVerletList.m
% ├─── selfVerletList.m
% ├─── updateVerletList.m
% └─── wallstress.m

% Dependencies from MS (INRAE/Molecular Studio)
% ├─── color_line3.m
% ├─── dispb.m
% ├─── dispf.m
% ├─── explore.m
% ├─── fileinfo.m
% ├─── lastdir.m
% ├─── MDunidrnd.m
% ├─── plot3D.m
% ├─── rootdir.m

% DUMP FILES included in this workshop
% ├─── dumps
% │    └─── hertz
% │        ├───
dump.ulsphBulk_hertzBoundary_referenceParameterExponent+1_with1SuspendedParti
cle             <== it is the original dump file
```

```
% |        └────
PREFETCH_dump.ulsphBulk_hertzBoundary_referenceParameterExponent+1_with1Suspe
ndedParticle    <-- the split folder
% |            ├────
TIMESTEP_000000000.mat
            <-- a split file
% |            ├────
TIMESTEP_000050000.mat
            <-- 158 splits (frames)
% |            ├────
TIMESTEP_000100000.mat
            <-- the value represent time
%              ...
```

STEP 1 - PREPROCESSING

Preprocess all the dumps (no need to precise the filenames, only the pattern).

Lamdumpread2 include() two PREPROCESSORS 'prefetch' and 'split'.

2D simulations

- prefetch should be preferred for 2D files (relatively smaller number of particles and many time frames)
- Usage: `lamdumpread2('dump.*','prefetch');`

3D simulations

- split should be preferred for large 3D files (large number of particles and a relatively smaller number of time frames)
- Usage: `lamdumpread2('dump.*','split');`

Note: this step should be used ONLY once, applying again will overwrite the previous splits (frames)

```
PREPROCESS_FLAG = true; % set it to true to preprocess your data
if PREPROCESS_FLAG
    datafolder = './dumps/';
    lamdumpread2(fullfile(datafolder,'dump.*'),'split'); % for large 3D
end
```

```
LAMPDUMPREAD AUTO 1 of 1
LAMMPS DUMP file...
    dump.ulsphBulk_hertzBoundary_referenceParameterExponent+1_with1SuspendedParticle       10-Mar-2023 15
[157:8450000] spl[last=8500000] 158 split files completed in 310 s
 in    ./dumps/hertz/PREFETCH_dump.ulsphBulk_hertzBoundary_referenceParameterExponent+1_with1SuspendedPart
ans = struct with fields:
           TIME: 17
       TIMESTEP: 8500000
         NUMBER: 313344
            BOX: [3×2 single]
          ATOMS: [313344×37 single]
    description: [1×1 struct]
            nfo: [1×1 struct]
```

STEP 2 - PROCESS SPECIFICALLY ONE FILE

we do work with one dump file

```
datafolder = './dumps/';
dumpfile =
'dump.ulsphBulk_hertzBoundary_referenceParameterExponent+1_with1SuspendedPart
icle';
datafolder = lamdumpread2(fullfile(datafolder,dumpfile),'search'); % fix
datafolder based on initial guess
```

```
Look for 'dump.ulsphBulk_hertzBoundary_referenceParameterExponent+1_with1SuspendedParticle'... (be patient
...found in './dumps/hertz'

The dumpfile 'dump.ulsphBulk_hertzBoundary_referenceParameterExponent+1_with1SuspendedParticle' has been f
    in the folder: ./dumps/hertz
the original search started in ./dumps
The frame (split) folder is: ./dumps/hertz/PREFETCH_dump.ulsphBulk_hertzBoundary_referenceParameterExponen
The first frame (split) is located in: ./dumps/hertz/PREFETCH_dump.ulsphBulk_hertzBoundary_referenceParame
The prefetch is split in several files.
158 TIMESTEPS are availble:
  Column 01      Column 02      Column 03      Column 04      Column 05      Column 06      Column 07
        0       800000      1600000      2400000      3200000      4650000      5450000      6250000
    50000       850000      1650000      2450000      3250000      4700000      5500000      6300000
   100000       900000      1700000      2500000      3300000      4750000      5550000      6350000
   150000       950000      1750000      2550000      3350000      4800000      5600000      6400000
   200000      1000000      1800000      2600000      3400000      4850000      5650000      6450000
   250000      1050000      1850000      2650000      3450000      4900000      5700000      6500000
   300000      1100000      1900000      2700000      4150000      4950000      5750000      6550000
   350000      1150000      1950000      2750000      4200000      5000000      5800000      6600000
   400000      1200000      2000000      2800000      4250000      5050000      5850000      6650000
   450000      1250000      2050000      2850000      4300000      5100000      5900000      6700000
   500000      1300000      2100000      2900000      4350000      5150000      5950000      6750000
   550000      1350000      2150000      2950000      4400000      5200000      6000000      6800000
   600000      1400000      2200000      3000000      4450000      5250000      6050000      6850000
   650000      1450000      2250000      3050000      4500000      5300000      6100000      6900000
   700000      1500000      2300000      3100000      4550000      5350000      6150000      6950000
   750000      1550000      2350000      3150000      4600000      5400000      6200000      7000000
Choose the time step you are interested in.
Only the first one is returned for now.
Use the prefetch (split: TIMESTEP 0) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_refere
    TIMESTEP_000000000.mat        25-Aug-2023 10:04:36        1.0 MBytes        ./dumps/hertz/PREFETCH_dum
...loaded in 0.284 s
```

```
defaultfiles = lamdumpread2(fullfile(datafolder,dumpfile),'default'); %
default folder (just for check)
```

Here, `datafolder` is set to the path containing the dump files, and `dumpfile` specifies the particular file to process.

The functions `lamdumpread2` with 'search' and 'default' flags are used to fix the data folder based on an initial guess and set default parameters, respectively.

Extract the types of atoms and the list of available frames

This step extracts essential information from the dump file, such as the types of atoms and the list of available frames, utilizing the `lamdumpread2` function.

```
X0 = lamdumpread2(fullfile(datafolder,dumpfile)); % default frame
```

```
The prefetch is split in several files.
158 TIMESTEPS are availble:
  Column 01      Column 02      Column 03      Column 04      Column 05      Column 06      Column 07
         0       800000      1600000      2400000      3200000      4650000      5450000      6250000
     50000       850000      1650000      2450000      3250000      4700000      5500000      6300000
    100000       900000      1700000      2500000      3300000      4750000      5550000      6350000
    150000       950000      1750000      2550000      3350000      4800000      5600000      6400000
    200000      1000000      1800000      2600000      3400000      4850000      5650000      6450000
    250000      1050000      1850000      2650000      3450000      4900000      5700000      6500000
    300000      1100000      1900000      2700000      4150000      4950000      5750000      6550000
    350000      1150000      1950000      2750000      4200000      5000000      5800000      6600000
    400000      1200000      2000000      2800000      4250000      5050000      5850000      6650000
    450000      1250000      2050000      2850000      4300000      5100000      5900000      6700000
    500000      1300000      2100000      2900000      4350000      5150000      5950000      6750000
    550000      1350000      2150000      2950000      4400000      5200000      6000000      6800000
    600000      1400000      2200000      3000000      4450000      5250000      6050000      6850000
    650000      1450000      2250000      3050000      4500000      5300000      6100000      6900000
    700000      1500000      2300000      3100000      4550000      5350000      6150000      6950000
    750000      1550000      2350000      3150000      4600000      5400000      6200000      7000000
Choose the time step you are interested in.
Only the first one is returned for now.
Use the prefetch (split: TIMESTEP 0) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_refere
    TIMESTEP_000000000.mat        25-Aug-2023 10:04:36        1.0 MBytes        ./dumps/hertz/PREFETCH_dum
...loaded in 0.231 s
```

```
natoms = X0.NUMBER;
timesteps = X0.TIMESTEPS;
atomtypes = unique(X0.ATOMS.type);
ntimesteps = length(timesteps);
```

- `X0`: Represents the default frame.
- `natoms`: Contains the total number of atoms.
- `timesteps`: Provides the list of available time steps.
- `atomtypes`: Holds the unique types of atoms.
- `ntimesteps`: Contains the total number of time steps.This step is crucial for understanding the data's structure and providing insights into the atom types and available frames.

Extract the middle frame (i.e. in the middle of the simulation duration)

This step concentrates on extracting the middle frame of the simulation duration. The default frame `X0` might be too far from the steady state for advanced analysis, so the middle frame is specifically targeted.

```
Xmiddle = lamdumpread2(fullfile(datafolder,dumpfile),'usesplit',
[],timesteps(ceil(ntimesteps/2))); % middle frame
```

```
Use the prefetch (split: TIMESTEP 4550000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004550000.mat        25-Aug-2023 10:07:08        9.0 MBytes        ./dumps/hertz/PREFETCH_dum
...loaded in 0.335 s
```

- `Xmiddle`: Represents the middle frame of the simulation, which is extracted using the `lamdumpread2` function with the `usesplit` flag.

Extract the number of beads for each type

In this step, the number of beads for each atom type is extracted. The most populated type is assumed to be the fluid, while the least populated type is assumed to be the particle.

```
T = X0.ATOMS.type;
natomspertype = arrayfun(@(t) length(find(T==t)),atomtypes);
[~,fluidtype] = max(natomspertype);
[~,solidtype] = min(natomspertype);
walltypes = setdiff(atomtypes,[fluidtype,solidtype]);
```

- `T`: Represents the types of atoms from the default frame.
- `natomspertype`: An array that contains the number of atoms for each type.
- `fluidtype`: Identifies the type corresponding to the fluid (the most populated).
- `solidtype`: Identifies the type corresponding to the particle (the least populated).
- `walltypes`: Contains the types other than fluid and solid.

This step assists in classifying the types of beads in the system and understanding their distribution, crucial for further analyses and simulations.

Estimate the fluid bead size

This step aims to estimate the size of the fluid bead. The calculation starts with an initial guess based on the assumption that the bead is cubic to estimate the cutoff, followed by a more refined estimation using the `buildVerletList()` function.

```
fluidxyz = X0.ATOMS{T==fluidtype,{'x','y','z'}};
fluidid = X0.ATOMS{T==fluidtype,'id'};
nfluidatoms = length(fluidid);
nsolidatoms = natomspertype(solidtype);
% first estimate assuming that the bead is a cube
boxdims = X0.BOX(:,2) - X0.BOX(:,1);
Vbead_guess = prod(boxdims)/natoms;
rbead_guess = (3/(4*pi)*Vbead_guess)^(1/3);
cutoff = 3*rbead_guess;
[verletList,cutoff,dmin,config,dist] = buildVerletList(fluidxyz,cutoff);
```

```
Build Verlet list by searching in blocks...
[BLOCK 375/729] 391 particles with 10017 neighbors (0.6 % of total considered) | min dist l:2.08e-05 g:2.0
```

```
rbead = dmin/2;
```

- `fluidxyz`: Coordinates of the fluid atoms.

- `fluidid`: IDs of the fluid atoms.
- `nfluidatoms`: Number of fluid atoms.
- `nsolidatoms`: Number of solid atoms (calculated based on the previously identified solid type).
- `rbead_guess`: Initial guess of bead radius.
- `cutoff`: Cutoff distance for the Verlet list.
- `rbead`: Final estimated bead radius.

The process estimates bead size using a specific tool (`buildVerletList`) designed to work with the physical arrangement of the beads. The accurate bead size is essential for subsequent calculations involving fluid dynamics and interactions.

STEP 7 - FINDING THE FLOW DIRECTION

This step is crucial for identifying the primary flow direction within the system. The main idea is to determine the largest dimension of the bounding box and assume that the fluid flows along this axis.

```
[~,iflow] = max(boxdims);
iothers = setdiff(1:size(X0.BOX,1),iflow);
```

- `fluidxyz`: Coordinates of the fluid atoms.
- `fluidid`: IDs of the fluid atoms.
- `nfluidatoms`: Number of fluid atoms.
- `nsolidatoms`: Number of solid atoms (calculated based on the previously identified solid type).
- `rbead_guess`: Initial guess of bead radius.
- `cutoff`: Cutoff distance for the Verlet list.
- `rbead`: Final estimated bead radius.

The process estimates bead size using a specific tool (`buildVerletList`) designed to work with the physical arrangement of the beads. The accurate bead size is essential for subsequent calculations involving fluid dynamics and interactions.

STEP 8 - SEPARATING TOP AND BOTTOM WALLS

In this simulation, two walls are present, and they move in opposite directions. This step serves to identify and separate the top and bottom walls based on their directional movement.

```
vel = {'vx','vy','vz'};
wall1vel = Xmiddle.ATOMS{Xmiddle.ATOMS.type==walltypes(1),vel{iflow}};
wall1vel = wall1vel(1);
wall2vel = Xmiddle.ATOMS{Xmiddle.ATOMS.type==walltypes(2),vel{iflow}};
wall2vel = wall2vel(1);
[wallvel,iwall] = sort([wall1vel,wall2vel],'descend'); % 1 is top (>0), 2 is
bottom;
walltypes = walltypes(iwall);
```

- `wall1vel` and `wall2vel`: Velocities of the first and second walls along the main flow direction (identified in STEP 7).
- The top wall's velocity is expected to be positive, and the bottom wall's velocity is expected to be negative.

STEP 9 - LOCATING THE PARTICLE (OBSTACLE) POSITION WITHIN THE FLOW

In this step, the position of the solid "BIG" particle (referred to as an "obstacle") within the flow is determined.

```
solidxyz = Xmiddle.ATOMS{T==solidtype,{'x','y','z'}};
solidid = Xmiddle.ATOMS{T==solidtype,'id'};
solidbox = [min(solidxyz);max(solidxyz)]';
```

- `solidxyz` stores the spatial coordinates of the particle, and `solidid` stores its unique identifier.
- The `solidbox` variable captures the bounding coordinates, which might be used to represent or analyze the particle's extent or confinement within the flow

STEP 10 - PICKING N PARTICLES RANDOMLY FROM THE LEFT INLET AND INCLUDED IN THE MASK OF THE SOLID (INITIAL FRAME)

In this step, a specific number of particles (n = 300) are randomly selected from the left inlet of the system and included within the mask of the solid structure. This selection helps simulate the initiation of flow and the behavior of the particles as they approach and interact with the solid structure.

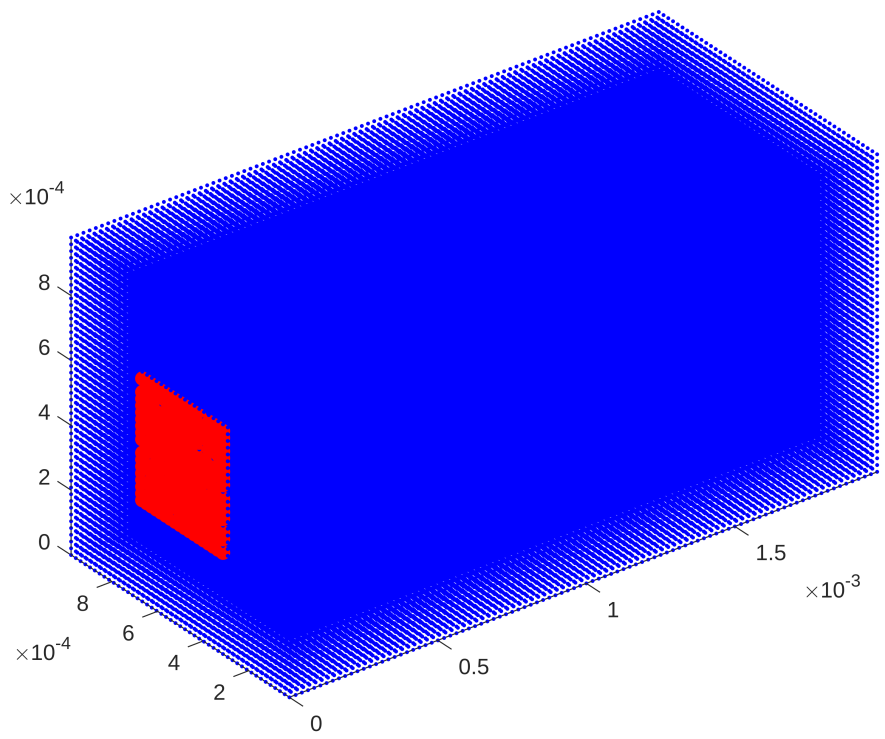
- Defining the Selection Parameters:

```
n = 300;
tol = 0.5; % add 40% particles around
selectionbox = NaN(3,2);
selectionbox(iflow,:) = [X0.BOX(iflow,1), X0.BOX(iflow,1)+2*rbead];
selectionbox(iothers,:) =  (1+tol)*(solidbox(iothers,2)-
solidbox(iothers,1))*[-1 1]/2 ...
    + (solidbox(iothers,1)+solidbox(iothers,2)) * [1 1]/2;
ok = true(nfluidatoms,1);
for c = 1:3
    ok = ok & (fluidxyz(:,c)>=selectionbox(c,1)) &
(fluidxyz(:,c)<=selectionbox(c,2));
end
icandidates = find(ok);
iselected = icandidates(MDunidrnd(length(icandidates),n));
selectedid = fluidid(iselected); % ID to be used
```

This portion of code locates the fluid particles within the selection box and picks n of them randomly.

- Visualization:

```
% plot selected particles and other ones
figure, hold on
plot3D(fluidxyz,'b.')
plot3D(fluidxyz(iselected,:),'ro','markerfacecolor','r')
plot3D(solidxyz,'ks','markerfacecolor','k')
view(3), axis equal
```



The code also provides a 3D visualization of the selected particles, allowing for an intuitive understanding of their initial placement and relationship to the solid structure.

STEP 11 - GENERATE THE TRAJECTORY FOR THE SELECTED PARTICLES (FOR ALL FRAMES)

The trajectories are determined across all frames of the simulation, providing a clear understanding of how the selected particles move and interact over time.

```
Xselection = lamdumpread2(fullfile(datafolder,dumpfile),'usesplit',
[],timesteps,selectedid);
```

```
Use the prefetch (split: TIMESTEP 0) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_refere
    TIMESTEP_000000000.mat        25-Aug-2023 10:04:36        1.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 50000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_re
    TIMESTEP_000050000.mat        25-Aug-2023 10:04:38        6.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 100000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000100000.mat        25-Aug-2023 10:04:40        7.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 150000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000150000.mat        25-Aug-2023 10:04:42        7.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 200000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
```

```
    TIMESTEP_000200000.mat        25-Aug-2023 10:04:43        7.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 250000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000250000.mat        25-Aug-2023 10:04:45        7.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 300000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000300000.mat        25-Aug-2023 10:04:47        7.4 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 350000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000350000.mat        25-Aug-2023 10:04:49        7.6 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 400000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000400000.mat        25-Aug-2023 10:04:51        7.6 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 450000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000450000.mat        25-Aug-2023 10:04:53        7.8 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 500000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000500000.mat        25-Aug-2023 10:04:55        7.8 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 550000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000550000.mat        25-Aug-2023 10:04:57        7.9 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 600000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000600000.mat        25-Aug-2023 10:04:59        8.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 650000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000650000.mat        25-Aug-2023 10:05:01        8.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 700000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000700000.mat        25-Aug-2023 10:05:03        8.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 750000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000750000.mat        25-Aug-2023 10:05:05        8.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 800000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000800000.mat        25-Aug-2023 10:05:07        8.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 850000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000850000.mat        25-Aug-2023 10:05:09        8.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 900000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000900000.mat        25-Aug-2023 10:05:11        8.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 950000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_r
    TIMESTEP_000950000.mat        25-Aug-2023 10:05:13        8.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1000000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001000000.mat        25-Aug-2023 10:05:15        8.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1050000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001050000.mat        25-Aug-2023 10:05:17        8.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1100000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001100000.mat        25-Aug-2023 10:05:19        8.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1150000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001150000.mat        25-Aug-2023 10:05:21        8.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1200000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001200000.mat        25-Aug-2023 10:05:23        8.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1250000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001250000.mat        25-Aug-2023 10:05:25        8.4 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1300000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001300000.mat        25-Aug-2023 10:05:26        8.4 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1350000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001350000.mat        25-Aug-2023 10:05:28        8.4 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1400000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001400000.mat        25-Aug-2023 10:05:30        8.5 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1450000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001450000.mat        25-Aug-2023 10:05:32        8.4 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1500000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001500000.mat        25-Aug-2023 10:05:34        8.4 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1550000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001550000.mat        25-Aug-2023 10:05:36        8.4 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1600000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001600000.mat        25-Aug-2023 10:05:38        8.5 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1650000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001650000.mat        25-Aug-2023 10:05:40        8.5 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1700000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001700000.mat        25-Aug-2023 10:05:42        8.5 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1750000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001750000.mat        25-Aug-2023 10:05:44        8.5 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1800000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
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    TIMESTEP_001800000.mat        25-Aug-2023 10:05:46        8.5 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1850000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001850000.mat        25-Aug-2023 10:05:48        8.6 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1900000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001900000.mat        25-Aug-2023 10:05:50        8.5 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 1950000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_001950000.mat        25-Aug-2023 10:05:52        8.6 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2000000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002000000.mat        25-Aug-2023 10:05:54        8.5 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2050000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002050000.mat        25-Aug-2023 10:05:56        8.6 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2100000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002100000.mat        25-Aug-2023 10:05:58        8.6 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2150000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002150000.mat        25-Aug-2023 10:06:00        8.6 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2200000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002200000.mat        25-Aug-2023 10:06:02        8.6 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2250000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002250000.mat        25-Aug-2023 10:06:04        8.6 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2300000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002300000.mat        25-Aug-2023 10:06:06        8.6 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2350000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002350000.mat        25-Aug-2023 10:06:08        8.7 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2400000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002400000.mat        25-Aug-2023 10:06:10        8.6 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2450000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002450000.mat        25-Aug-2023 10:06:12        8.6 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2500000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002500000.mat        25-Aug-2023 10:06:14        8.6 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2550000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002550000.mat        25-Aug-2023 10:06:16        8.6 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2600000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002600000.mat        25-Aug-2023 10:06:18        8.7 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2650000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002650000.mat        25-Aug-2023 10:06:19        8.7 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2700000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002700000.mat        25-Aug-2023 10:06:21        8.7 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2750000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002750000.mat        25-Aug-2023 10:06:23        8.7 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2800000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002800000.mat        25-Aug-2023 10:06:25        8.7 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2850000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002850000.mat        25-Aug-2023 10:06:27        8.7 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2900000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002900000.mat        25-Aug-2023 10:06:29        8.7 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 2950000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_002950000.mat        25-Aug-2023 10:06:31        8.7 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 3000000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_003000000.mat        25-Aug-2023 10:06:33        8.7 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 3050000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_003050000.mat        25-Aug-2023 10:06:35        8.7 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 3100000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_003100000.mat        25-Aug-2023 10:06:37        8.7 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 3150000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_003150000.mat        25-Aug-2023 10:06:39        8.8 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 3200000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_003200000.mat        25-Aug-2023 10:06:41        8.8 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 3250000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_003250000.mat        25-Aug-2023 10:06:43        8.8 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 3300000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_003300000.mat        25-Aug-2023 10:06:45        6.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 3350000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_003350000.mat        25-Aug-2023 10:06:47        8.8 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 3400000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
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    TIMESTEP_003400000.mat        25-Aug-2023 10:06:48        8.8 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 3450000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_003450000.mat        25-Aug-2023 10:06:50        7.8 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4150000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004150000.mat        25-Aug-2023 10:06:52        9.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4200000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004200000.mat        25-Aug-2023 10:06:54        9.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4250000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004250000.mat        25-Aug-2023 10:06:56        9.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4300000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004300000.mat        25-Aug-2023 10:06:58        9.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4350000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004350000.mat        25-Aug-2023 10:07:00        9.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4400000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004400000.mat        25-Aug-2023 10:07:02        9.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4450000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004450000.mat        25-Aug-2023 10:07:04        9.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4500000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004500000.mat        25-Aug-2023 10:07:06        9.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4550000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004550000.mat        25-Aug-2023 10:07:08        9.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4600000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004600000.mat        25-Aug-2023 10:07:10        9.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4650000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004650000.mat        25-Aug-2023 10:07:12        9.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4700000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004700000.mat        25-Aug-2023 10:07:14        9.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4750000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004750000.mat        25-Aug-2023 10:07:16        9.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4800000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004800000.mat        25-Aug-2023 10:07:18        9.0 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4850000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004850000.mat        25-Aug-2023 10:07:20        9.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4900000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004900000.mat        25-Aug-2023 10:07:22        9.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 4950000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_004950000.mat        25-Aug-2023 10:07:24        9.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5000000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005000000.mat        25-Aug-2023 10:07:26        9.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5050000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005050000.mat        25-Aug-2023 10:07:28        9.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5100000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005100000.mat        25-Aug-2023 10:07:30        9.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5150000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005150000.mat        25-Aug-2023 10:07:32        9.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5200000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005200000.mat        25-Aug-2023 10:07:34        9.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5250000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005250000.mat        25-Aug-2023 10:07:36        9.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5300000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005300000.mat        25-Aug-2023 10:07:38        9.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5350000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005350000.mat        25-Aug-2023 10:07:39        9.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5400000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005400000.mat        25-Aug-2023 10:07:41        9.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5450000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005450000.mat        25-Aug-2023 10:07:43        9.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5500000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005500000.mat        25-Aug-2023 10:07:45        9.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5550000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005550000.mat        25-Aug-2023 10:07:47        9.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5600000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005600000.mat        25-Aug-2023 10:07:49        9.1 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5650000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
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    TIMESTEP_005650000.mat        25-Aug-2023 10:07:51        9.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5700000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005700000.mat        25-Aug-2023 10:07:53        9.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5750000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005750000.mat        25-Aug-2023 10:07:55        9.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5800000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005800000.mat        25-Aug-2023 10:07:57        9.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5850000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005850000.mat        25-Aug-2023 10:07:59        9.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5900000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005900000.mat        25-Aug-2023 10:08:01        9.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 5950000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_005950000.mat        25-Aug-2023 10:08:03        9.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6000000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006000000.mat        25-Aug-2023 10:08:05        9.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6050000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006050000.mat        25-Aug-2023 10:08:07        9.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6100000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006100000.mat        25-Aug-2023 10:08:09        9.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6150000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006150000.mat        25-Aug-2023 10:08:11        9.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6200000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006200000.mat        25-Aug-2023 10:08:13        9.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6250000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006250000.mat        25-Aug-2023 10:08:15        9.2 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6300000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006300000.mat        25-Aug-2023 10:08:17        9.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6350000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006350000.mat        25-Aug-2023 10:08:19        9.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6400000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006400000.mat        25-Aug-2023 10:08:21        9.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6450000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006450000.mat        25-Aug-2023 10:08:23        9.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6500000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006500000.mat        25-Aug-2023 10:08:25        9.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6550000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006550000.mat        25-Aug-2023 10:08:27        9.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6600000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006600000.mat        25-Aug-2023 10:08:29        9.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6650000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006650000.mat        25-Aug-2023 10:08:31        9.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6700000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006700000.mat        25-Aug-2023 10:08:33        9.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6750000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006750000.mat        25-Aug-2023 10:08:35        9.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6800000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006800000.mat        25-Aug-2023 10:08:37        9.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6850000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006850000.mat        25-Aug-2023 10:08:39        9.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6900000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006900000.mat        25-Aug-2023 10:08:40        9.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 6950000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_006950000.mat        25-Aug-2023 10:08:42        9.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 7000000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007000000.mat        25-Aug-2023 10:08:44        9.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 7050000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007050000.mat        25-Aug-2023 10:08:46        9.3 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 7100000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007100000.mat        25-Aug-2023 10:08:48        9.4 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 7150000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007150000.mat        25-Aug-2023 10:08:50        9.4 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 7200000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007200000.mat        25-Aug-2023 10:08:52        9.4 MBytes        ./dumps/hertz/PREFETCH_dum
Use the prefetch (split: TIMESTEP 7250000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
```

```
    TIMESTEP_007250000.mat        25-Aug-2023 10:08:54        9.4 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 7300000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007300000.mat        25-Aug-2023 10:08:56        9.4 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 7350000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007350000.mat        25-Aug-2023 10:08:58        9.4 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 7400000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007400000.mat        25-Aug-2023 10:09:00        9.4 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 7450000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007450000.mat        25-Aug-2023 10:09:02        9.4 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 7500000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007500000.mat        25-Aug-2023 10:09:04        9.4 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 7550000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007550000.mat        25-Aug-2023 10:09:06        9.4 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 7600000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007600000.mat        25-Aug-2023 10:09:08        9.4 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 7650000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007650000.mat        25-Aug-2023 10:09:10        9.4 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 7700000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007700000.mat        25-Aug-2023 10:09:12        9.4 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 7750000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007750000.mat        25-Aug-2023 10:09:14        9.5 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 7800000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007800000.mat        25-Aug-2023 10:09:16        9.5 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 7850000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007850000.mat        25-Aug-2023 10:09:18        9.5 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 7900000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007900000.mat        25-Aug-2023 10:09:20        9.5 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 7950000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_007950000.mat        25-Aug-2023 10:09:22        9.5 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 8000000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_008000000.mat        25-Aug-2023 10:09:24        9.5 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 8050000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_008050000.mat        25-Aug-2023 10:09:26        9.5 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 8100000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_008100000.mat        25-Aug-2023 10:09:28        9.5 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 8150000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_008150000.mat        25-Aug-2023 10:09:30        9.5 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 8200000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_008200000.mat        25-Aug-2023 10:09:32        9.5 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 8250000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_008250000.mat        25-Aug-2023 10:09:34        9.5 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 8300000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_008300000.mat        25-Aug-2023 10:09:36        9.5 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 8350000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_008350000.mat        25-Aug-2023 10:09:38        9.5 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 8400000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_008400000.mat        25-Aug-2023 10:09:40        9.5 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 8450000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_008450000.mat        25-Aug-2023 10:09:42        9.5 MBytes        ./dumps/hertz/PREFETCH_dum
 Use the prefetch (split: TIMESTEP 8500000) folder (instead of './dumps/hertz/dump.ulsphBulk_hertzBoundary_
    TIMESTEP_008500000.mat        25-Aug-2023 10:09:44        9.5 MBytes        ./dumps/hertz/PREFETCH_dum
 ...loaded in 36.8 s
```

Here, the function `lamdumpread2` is called with specific parameters to load the data pertaining to the selected particles' trajectories:

- `fullfile(datafolder,dumpfile)`: Specifies the location of the file containing the dump data.
- `'usesplit'`: An option indicating that each split (subdivision of data) is loaded individually.
- `timesteps`: Represents the time steps in the simulation for which the trajectories are to be generated.
- `selectedid`: The IDs of the selected particles whose trajectories are to be generated.

By specifying these parameters, the function reads only the required data for the selected particles, thus optimizing the process.

STEP 12 - COLLECT THE TRAJECTORY OF THE SOLID PARTICLE FOR ALL FRAMES

This step involves the collection of the trajectory data for the solid obstacle (or particles, if there are multiple solid particles being considered) throughout the entire simulation. It provides a continuous record of the solid particle's position and motion, allowing for a detailed analysis of its behavior.

- Command to Retrieve the Trajectory of Solid Particles Consiting in The Obstacle:

```
Xsolid = lamdumpread2(fullfile(datafolder,dumpfile),'usesplit',
[],timesteps,solidid);
```

- `fullfile(datafolder,dumpfile)`: Specifies the path to the dump file containing the simulation data.
- `'usesplit'`: A parameter indicating that each split is loaded individually, enhancing efficiency.
- `timesteps`: Specifies the time steps in the simulation for which the solid particle's trajectory is to be extracted.
- `solidid`: The ID or IDs of the solid particle(s) whose trajectory is being retrieved.

STEP 13 - STORE THE TRAJECTORIES IN AN $ntimesteps \times 3 \times n$ MATRIX

This step entails storing the trajectories of the selected fluid and solid particles in a structured matrix. Incomplete frames, a common occurrence in LAMMPS, are handled, and missing data are kept as NaN (Not a Number).

Initialization of Variables:

- Trajectories and velocities of selected fluid particles: `seltraj` and `selveloc`.
- Trajectory of solid particles: `solidtraj`.
- A boolean variable to indicate good frames: `goodframes`.

Looping through Time Steps:The loop iterates through each time step, handling fluid and solid atoms separately:

Fluid Atoms:

- Reading the frame for selected fluid atoms.
- If the frame is incomplete (missing atoms), a warning is displayed, and the available data are stored at the corresponding indices. The missing data are kept as NaN.
- If the frame is complete, the trajectory and velocity data are stored.

Solid Atoms:

- Reading the frame for solid atoms.
- Similar to the fluid atoms, the trajectory data are stored, handling incomplete frames if necessary.

Velocity Magnitude Calculation:

- The magnitude of the velocity for the fluid particles is computed and stored.

Interpretation of Solid Deformation:

- Solid deformation is interpreted through calculations involving moments of inertia I_{xx}, I_{yy}, I_{zz} and Tailor deformation D.
- Centered solid trajectory is computed using `centeredsolidtraj`.

```
[seltraj,selveloc] = deal(NaN(ntimesteps,3,n,'single'));
solidtraj = NaN(ntimesteps,3,nsolidatoms,'double');
goodframes = true(ntimesteps,1);
for it = 1:ntimesteps
    % read fluid atoms
    selframe = Xselection.ATOMS(Xselection.ATOMS{:,'TIMESTEP'} ==
timesteps(it),:);
    nfoundatoms = size(selframe,1);
    if nfoundatoms<n % incomplete dumped frame (it may happen in LAMMPS)
        dispf('incomplete frame %d/%d (t=%0.4g): %d of %d fluid atoms
missing',it,ntimesteps,timesteps(it),n-nfoundatoms,n)
        [~,iatoms,jatoms] = intersect(selectedid,selframe.id,'stable');
        seltraj(it,:,iatoms) = permute(selframe{jatoms,{'x','y','z'}},[3 2
1]);
        goodframes(it) = false;
    else
        seltraj(it,:,:) = permute(selframe{:,{'x','y','z'}},[3 2 1]);
        selveloc(it,:,:) = permute(selframe{:,{'vx','vy','vz'}},[3 2 1]);
    end
    % read solid atoms
    solidframe = Xsolid.ATOMS(Xsolid.ATOMS{:,'TIMESTEP'} == timesteps(it),:);
    nfoundatoms = size(solidframe,1);
    if nfoundatoms<nsolidatoms % incomplete dumped frame (it may happen in
LAMMPS)
        dispf('incomplete frame %d/%d (t=%0.4g): %d of %d solid atoms
missing',it,ntimesteps,timesteps(it),nsolidatoms-nfoundatoms,nsolidatoms)
        [~,iatoms,jatoms] = intersect(solidid,solidframe.id,'stable');
        solidtraj(it,:,iatoms) = permute(solidframe{jatoms,{'x','y','z'}},[3
2 1]);
        goodframes(it) = false;
    else
        solidtraj(it,:,:) = permute(solidframe{:,{'x','y','z'}},[3 2 1]);
    end
end
% velocity magnitude for the fluid particles
```

```
selveloc_magnitude = squeeze(sqrt(sum(selveloc.^2, 2)));

% Interpertation of the solid deformation via Ixx, Iyy, Izz and D
centeredsolidtraj = solidtraj - repmat(nanmean(solidtraj,3),1,1,nsolidatoms);
```

Comments:

- By storing the trajectory information in structured matrices, subsequent analysis, visualization, and interpretation become more efficient and coherent.
- Handling incomplete frames ensures that the analysis can proceed without disruption, providing as much information as possible despite the missing data.
- Code Segment:The given code segment meticulously details how to perform these operations, using loops to iterate through time steps, conditional statements to handle incomplete frames, and mathematical operations to compute relevant quantities.

STEP 14 - CALCULATE THE APPROXIMATE MAJOR AND MINOR AXES (ASSUMING AN ELLIPSOIDAL SHAPE)

This step is centered around building the inertia tensor and calculating the approximate major and minor axes of the solid particle, assuming an ellipsoidal shape. It also calculates the Taylor deformation over time.

Initialization of Moments of Inertia:

- Three variables `Ixx`, `Iyy`, and `Izz` are initialized to store the principal moments of inertia for each time step.
- Loop through Time Steps:The process iterates through each time step, performing the following:

Extraction of Coordinates:

- The centered solid trajectory for the current time step is extracted into a matrix `coordinates`.
- Computation of the Covariance Matrix:
- A covariance matrix `C` is calculated by multiplying `coordinates` with its transpose and normalizing by the number of solid atoms.

Singular Value Decomposition (SVD):

- SVD is performed on the covariance matrix, resulting in matrices `U` and `S`.
- Storage of Principal Moments of Inertia:
- The principal moments of inertia are extracted from the diagonal of `S` and stored in `Ixx`, `Iyy`, and `Izz`.

Approximation of Major and Minor Axes:

- The major (`L`) and minor (`B`) axes are calculated using the principal moments of inertia, assuming an ellipsoidal shape for the solid particle.
- Calculation of the Taylor Deformation:
- The Taylor deformation `D` is calculated using the major and minor axes.

```
% Building the inertia tensor

% Initialize moments of inertia
Ixx = zeros(ntimesteps, 1);
Iyy = zeros(ntimesteps, 1);
Izz = zeros(ntimesteps, 1);

for it = 1:ntimesteps
    % Extract the 3 x natoms matrix for the current timestep
    coordinates = squeeze(centeredsolidtraj(it, :, :))';

    % Compute the covariance matrix
    C = coordinates' * coordinates / nsolidatoms;

    % Perform Singular Value Decomposition
    [U, S, ~] = svd(C);

    % The principal moments of inertia are on the diagonal of S
    Ixx(it) = S(1, 1);
    Iyy(it) = S(2, 2);
    Izz(it) = S(3, 3);
end
% Calculate the approximate major and minor axes (assuming an ellipsoidal
shape)
L = sqrt(5 * (Ixx + Iyy - Izz) / 2); % Major axis (approximation)
B = sqrt(5 * (Ixx - Iyy + Izz) / 2); % Minor axis (approximation)
% Calculate the Taylor deformation
D = (L - B) ./ (L + B);
```

Plotting Taylor Deformation Over Time:

- A plot is generated to visualize the Taylor deformation over time, providing insights into the deformation behavior of the solid particle.
- Significance:
- The calculated major and minor axes provide valuable geometric insights into the solid particle's shape.
- The Taylor deformation offers a quantitative measure of deformation, which may be crucial for understanding fluid-solid interactions and material properties.

Significance:

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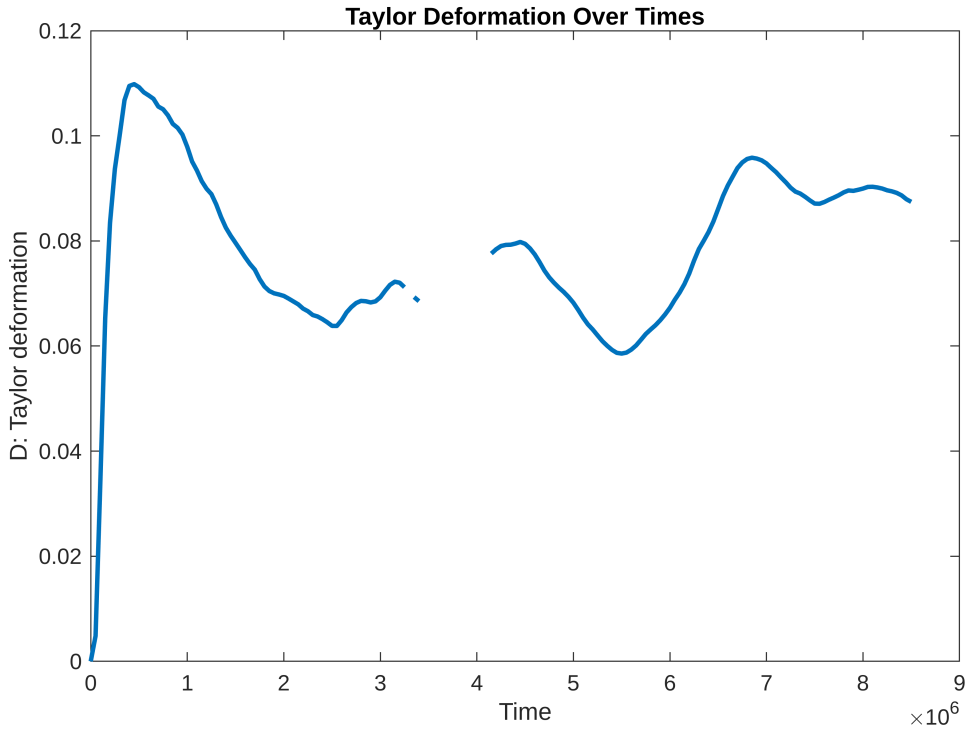
- The Taylor deformation offers a quantitative measure of deformation, which may be crucial for understanding fluid-solid interactions and material properties.

```
figure;
plot(timesteps, D,'-','linewidth',2);
xlabel('Time'); ylabel('D: Taylor deformation');
```

```
title({'\rm{' strrep(dumpfile, '_', '\_') '}:' '\bf{Taylor Deformation Over
Times}'}, 'Interpreter', 'tex')
```

:
dump.ulsphBulk_hertzBoundary_referenceParameterExponent+1_with1SuspendedParticle



Summary

Step 14 involves complex mathematical calculations, including matrix multiplication, singular value decomposition, and geometric approximations. These are used to derive key quantities like the principal moments of inertia, major and minor axes, and the Taylor deformation. This step bridges the gap between the raw simulation data and actionable insights into the solid particle's behavior within the fluid. It's an essential step towards a comprehensive understanding of the system, laying the groundwork for more specialized analyses.

STEP 15 - PLOT THE TRAJECTORIES FOR THE SELECTED PARTICLES (STREAMLINES WITH COLOR REPRESENTING VELOCITY MAGNITUDE)

This step focuses on visualizing the trajectories of selected fluid particles alongside the solid particle within the simulated domain. Streamlines are used to represent the paths of the fluid particles, and the color of these lines is associated with the velocity magnitude.

Create Figure:

- A new figure is created, and the plot hold state is turned on to allow multiple plots on the same axes.

Color Scheme:

- A colormap `col` is defined using the `parula` function, which will be used to color the streamlines based on velocity magnitude.

Loop through Particles:

- The process iterates through each of the selected `n` particles, performing the following:
- Find Jumps:
- The `jumps` variable is defined to identify discontinuities in the trajectories that arise from periodic boundary conditions.

Plot Streamlines:

- For each segment between jumps, the streamline for the particle is plotted using the `color_line3` function. This function takes the `x`, `y`, `z` coordinates of the streamline and the corresponding velocity magnitude, creating a three-dimensional line plot with color corresponding to velocity.
- Alternative Plotting Method (commented out):
- An alternative, faster method is also provided in the comments, using the `plot3` function, which plots the trajectory without the streamline effect.

Plot Solid Particle:

- The solid particle is plotted using `plot3D`, represented by black filled circles.

View Settings:

- The plot view is set to 3D, and the axes are made equal to properly display the geometrical relationships.
- Title and Labels:
- The title, labels for the axes, and a colorbar are added to describe the plot, with LaTeX formatting to represent special characters.
- Significance:
- This step provides a visual representation of the movement of the selected fluid particles around the solid obstacle, effectively linking the numerical data from the simulation with a visual, human-understandable form.
- By color-coding the velocity, this plot helps in understanding the fluid dynamics and interactions around the solid particle, especially the spatial distribution of velocity.

Significance:

- This step provides a visual representation of the movement of the selected fluid particles around the solid obstacle, effectively linking the numerical data from the simulation with a visual, human-understandable form.
- By color-coding the velocity, this plot helps in understanding the fluid dynamics and interactions around the solid particle, especially the spatial distribution of velocity.

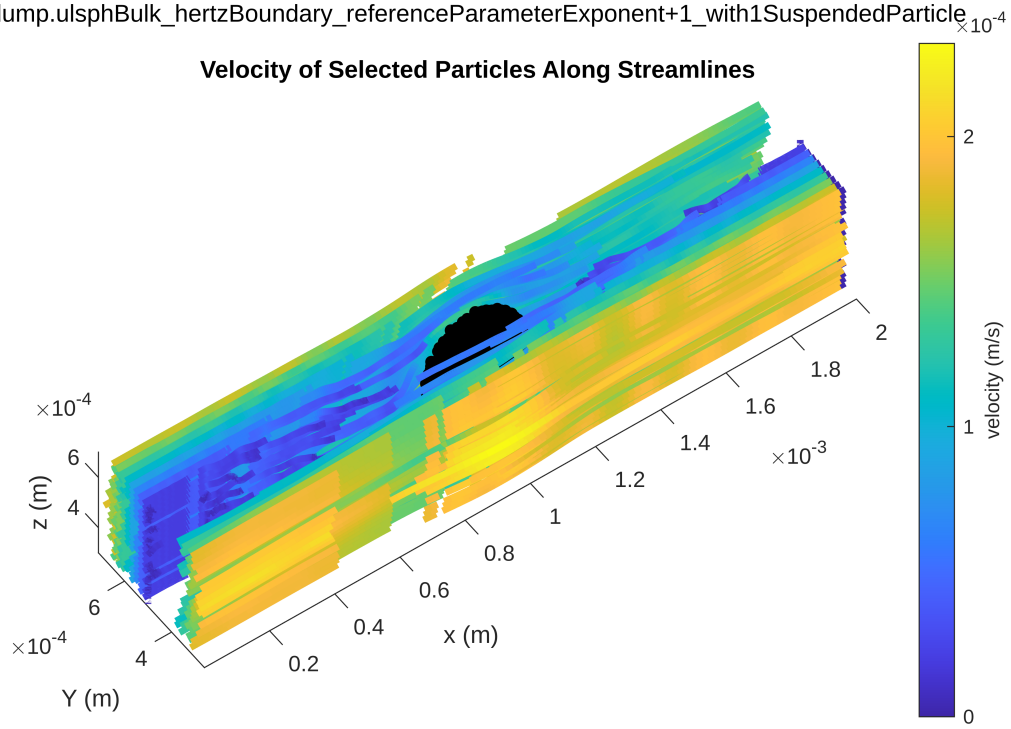
```
figure, hold on
col = parula(n);
```

```
for i=1:n
    jumps = [1;ntimesteps+1];
    for d=1:3
        jumps = unique([jumps;find(abs(diff(seltraj(:,d,i)))>boxdims(d)/
2)+1]);
    end
    for j=1:length(jumps)-1
        u = jumps(j):jumps(j+1)-1;
        streamline = seltraj(u, :, i);
        color_line3(streamline(:, 1), streamline(:, 2), streamline(:, 3),
selveloc_magnitude(u, i), 'linewidth', 3);
        % faster method but without streamline

%plot3(traj(u,1,i),traj(u,2,i),traj(u,3,i),'-','linewidth',3,'color',col(i,:)
)
    end
end
plot3D(solidxyz,'ko','markerfacecolor','k','markersize',5)
view(3), axis equal
title({'\rm{' strrep(dumpfile, '_', '\_') '}:' '\bf{Velocity of Selected
Particles Along Streamlines}'}, 'Interpreter', 'tex')
xlabel('x (m)'), ylabel('Y (m)'), zlabel('z (m)')
hc = colorbar; hc.Label.String = 'velocity (m/s)';
view([-35.851023 51.372457])
```

:

dump.ulsphBulk_hertzBoundary_referenceParameterExponent+1_with1SuspendedParticle



Summary: Step 15 combines numerical data processing (Lagrangian description) with visualization techniques to create a graphical representation of the selected particles' movement (trajectories matching streamlines at the steady state). This plot can be an essential tool for understanding and analyzing the turbulence deveopping in the wake flow.