Experimental reconstruction of the unfolding process of the electromagnetically launched flexible tethered net

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PaperID:2024076

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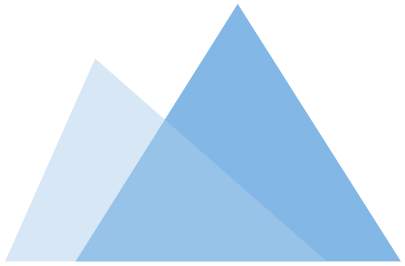


1 Research Background

2 Research Content

3 Innovative Aspects of the Content

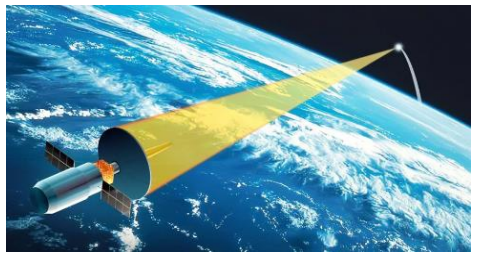
4 Research Outlook

1.Research Background—Methods of Capturing Space Debris

Space Debris

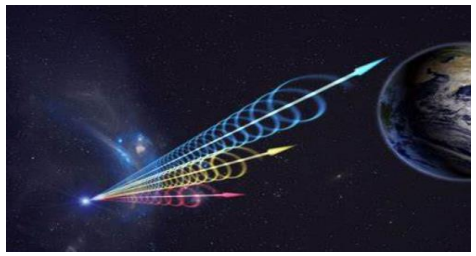
Robotic Arm

- High Costs



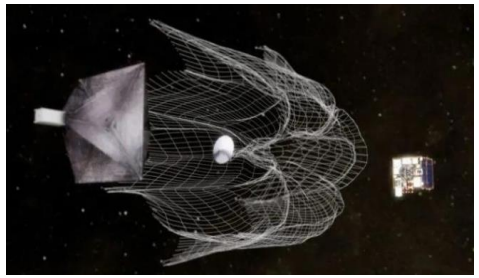
Laser Propulsion

- High Precision



Electromagnetic Pulse

- High Energy Support



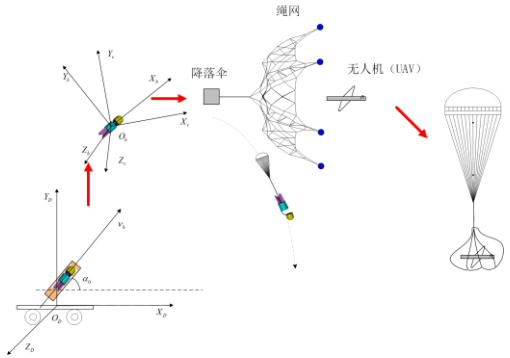
Net Capture

1.Non-destructive Capture
2.Efficient Coverage Range
3.Flexibility and Adaptability
4.Operational Safety
5.Technological Scalability

1.Research Background—Current Research Status of Net Launching

European Space Agency (ESA) e.Deorbit Project (Spring)

- Difficulty in controlling launch velocity



Unmanned Aerial Vehicle Capture and Recovery Scheme (Fire Control)

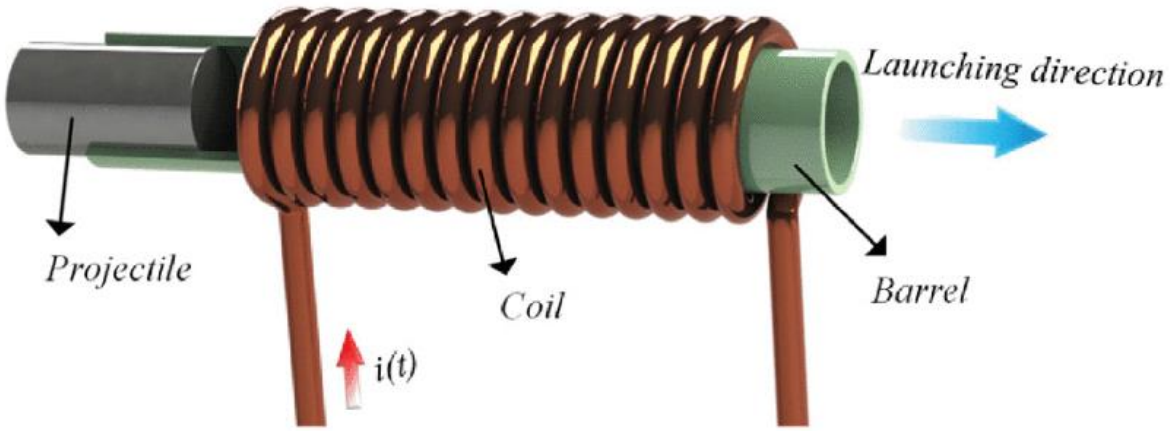
- Low Launch Safety

University at Buffalo - Net Capture Device (High-Pressure Gas)

- Low Launch Safety

Net Rotation Unfolding (Electric Motor)

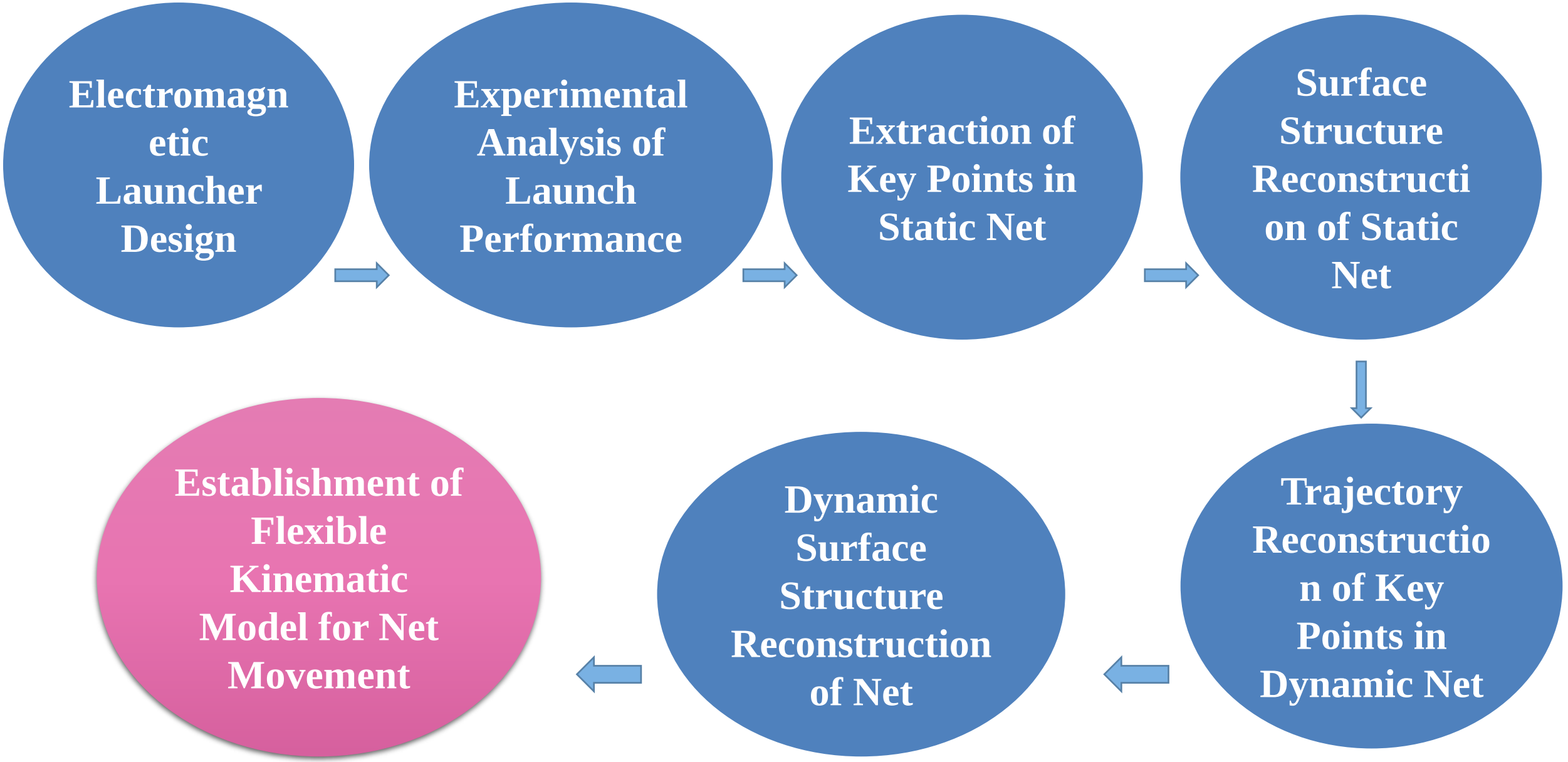
- Complex Structure



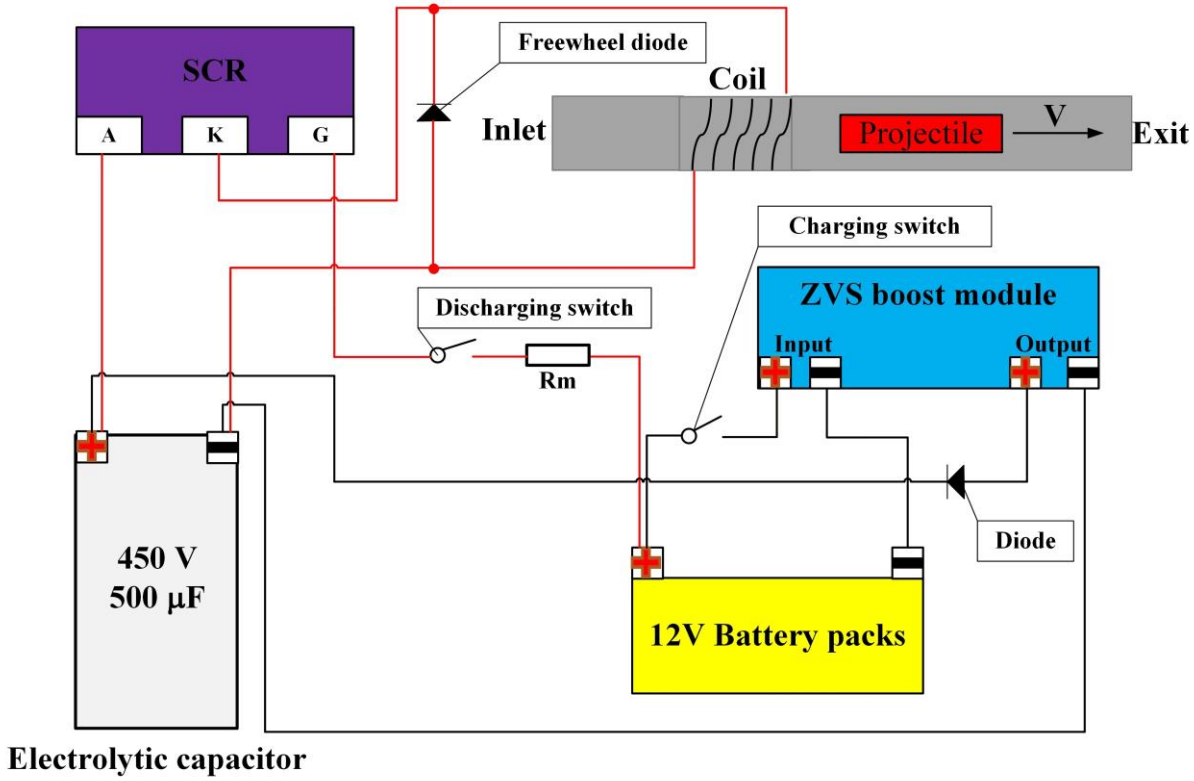
Electromagnetic Launch Technology

- Short Acceleration Time, Fast Exit Velocity, Lower Control Difficulty

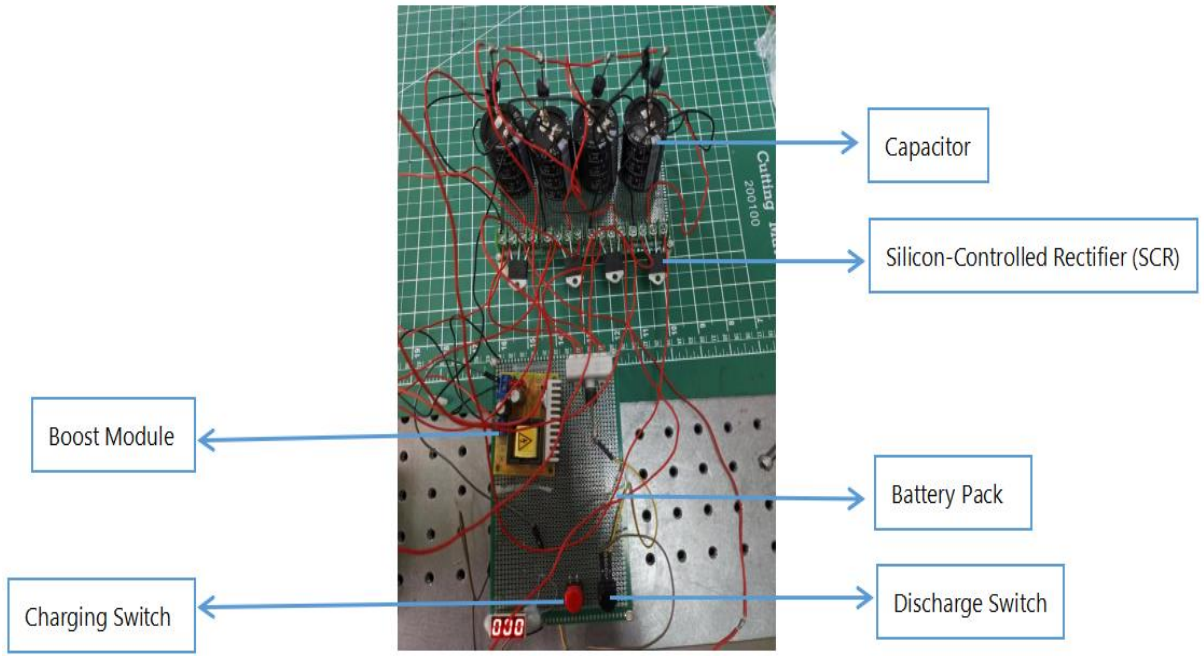
2. Research Content—Research Plan



2. Research Content—Electromagnetic Launcher Design

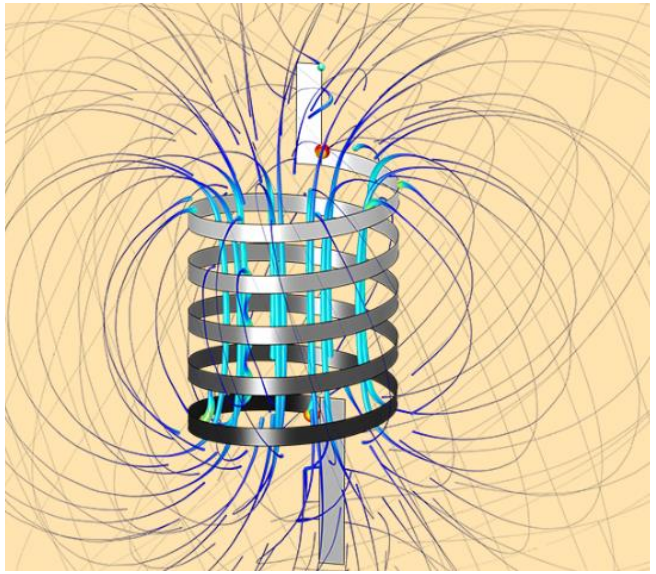


circuit design

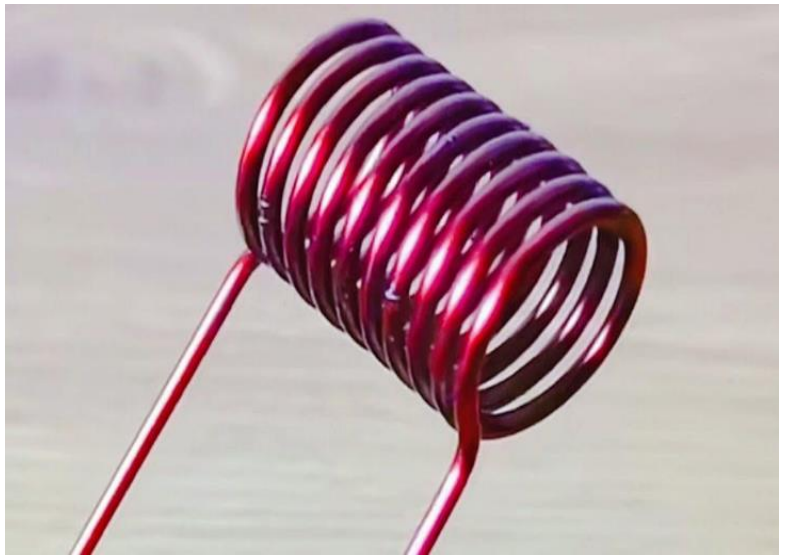


Control Circuit

2. Research Content—Electromagnetic Launcher Design

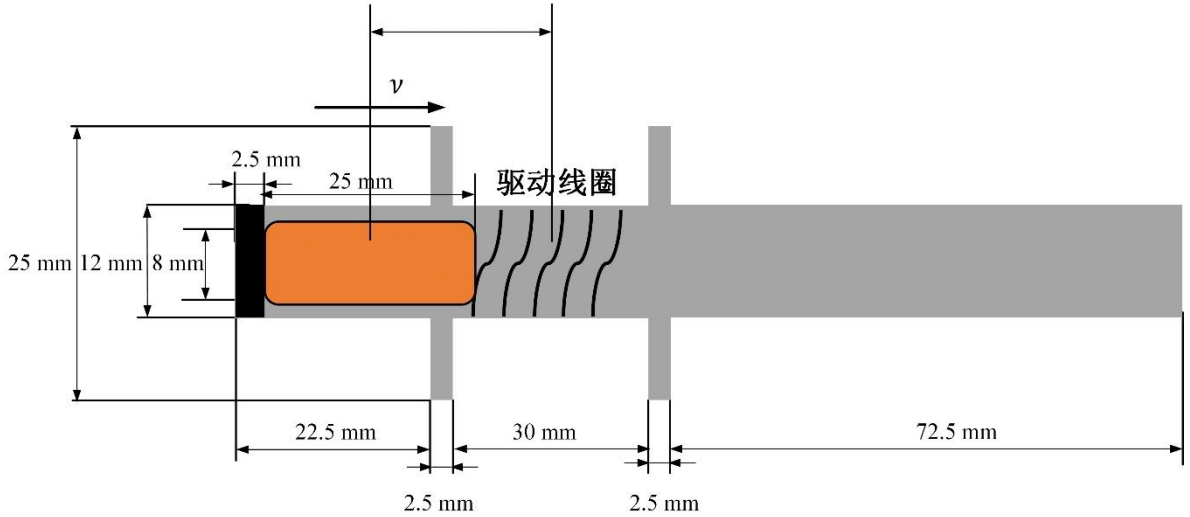


magnetic field



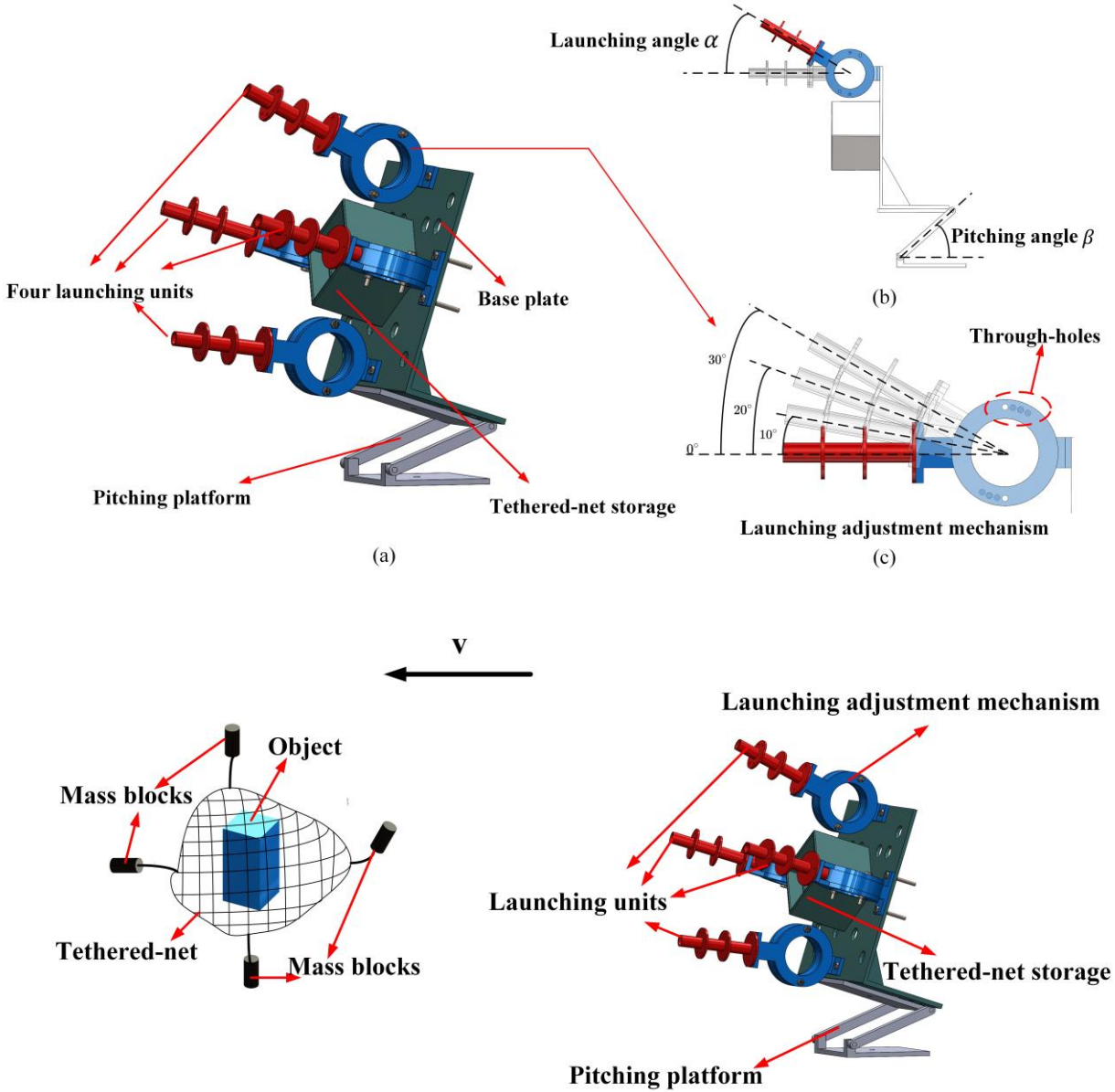
copper coil

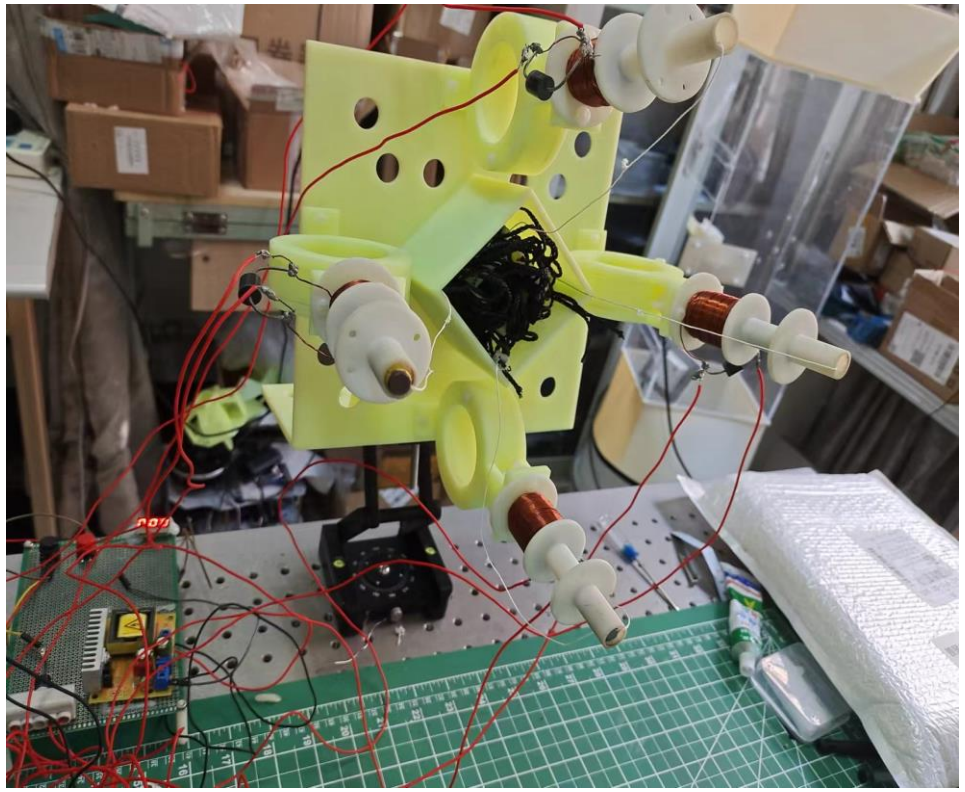
iron mass block



The electromagnetic force ejects the iron mass block

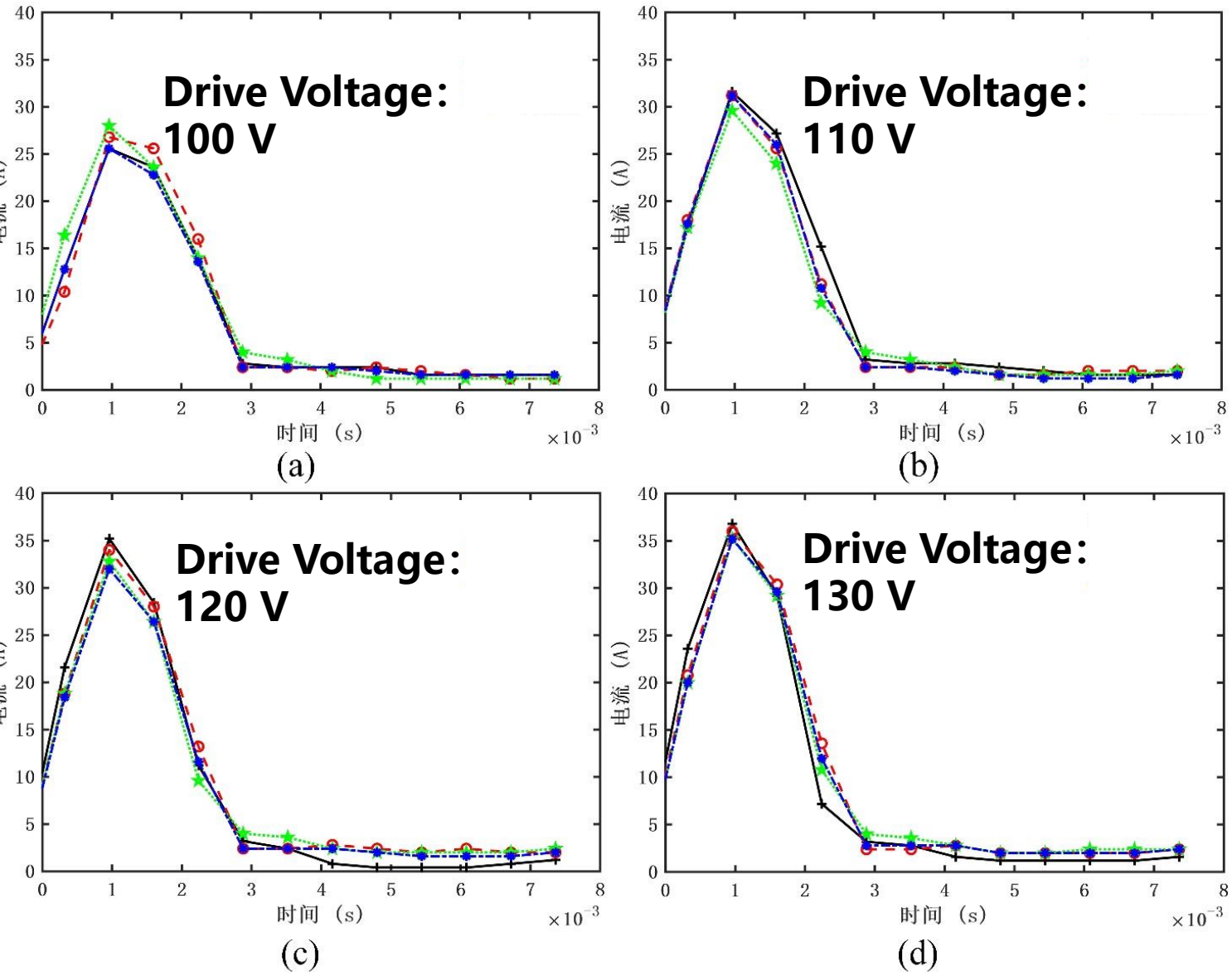
2. Research Content—Electromagnetic Launcher Design





Physical Diagram

2. Research Content—Experimental Analysis of Launch Performance

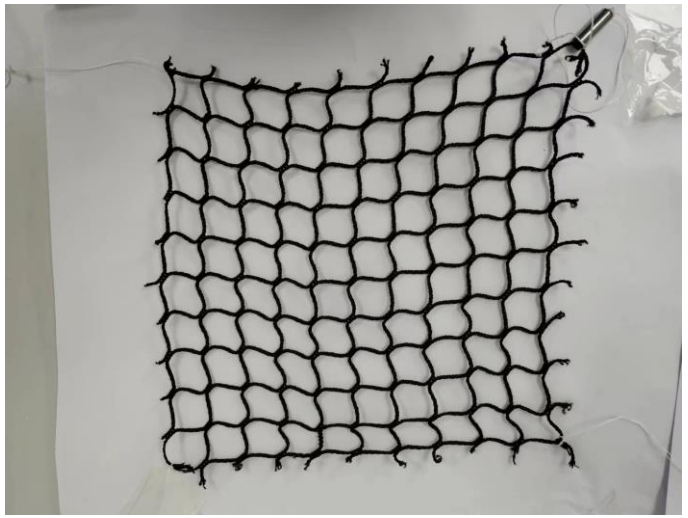


1.The current variation curves in the four coils are basically consistent.

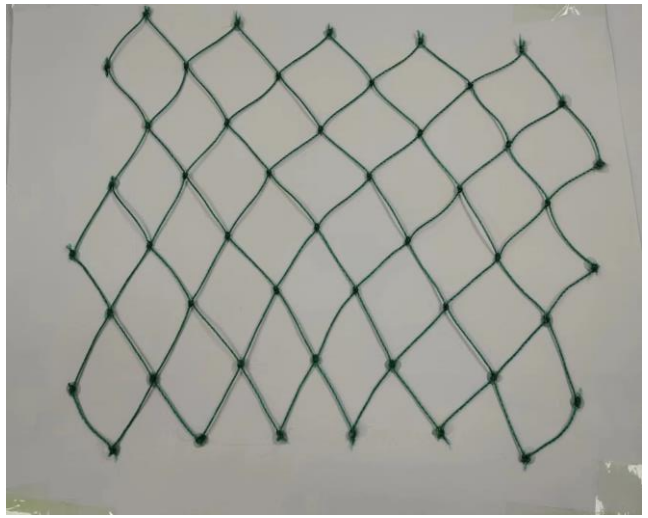
2.When the voltage reaches 120V, the net can fully unfold.

2. Research Content—Experimental Analysis of Launch Performance

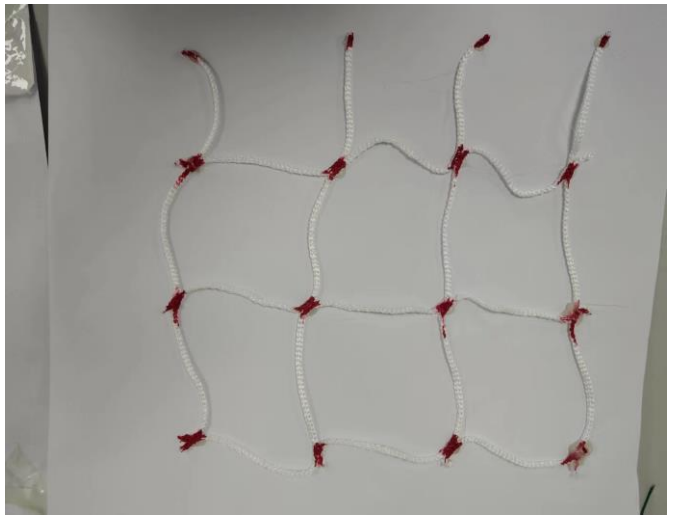
Impact of Net Material and Shape on Launch



- **The net opening is too small, causing significant motion blur during dynamic movement, affecting analysis.**



- **The net is too light, resulting in excessive altitude during launch and inability to fully unfold.**



- **The net has a good shape and optical markers have been added, enabling effective capture of motion trajectories.**

2. Research Content

Overall Scene Setup

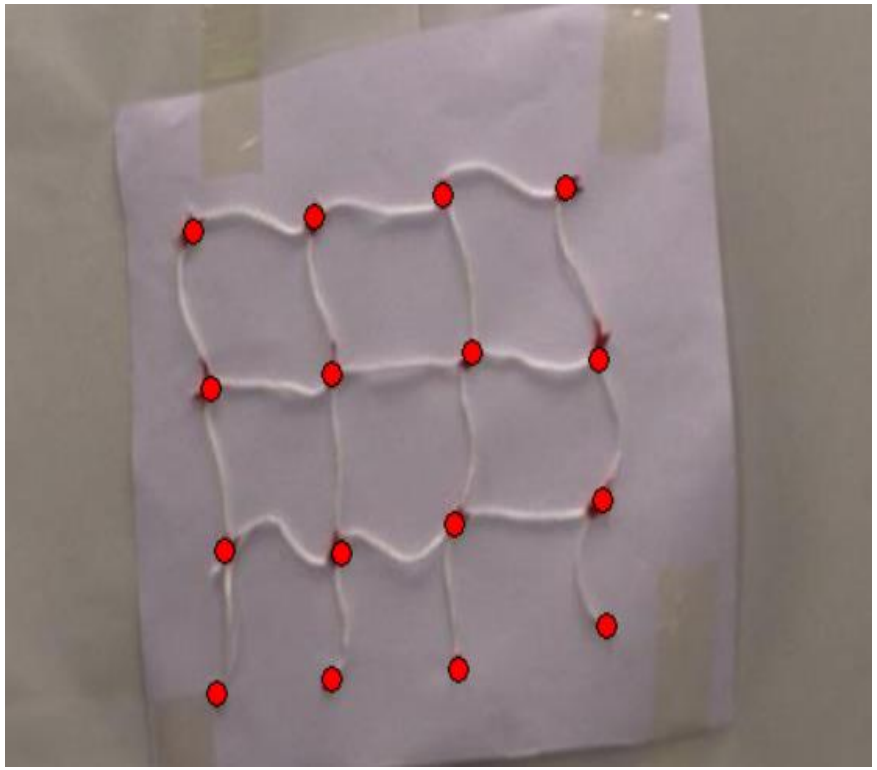
2. Research Content—Extraction of Key Points in Static Net

Harris

- **Severe Clustering Phenomenon**

SIFT

- **Key Points Cluttered**

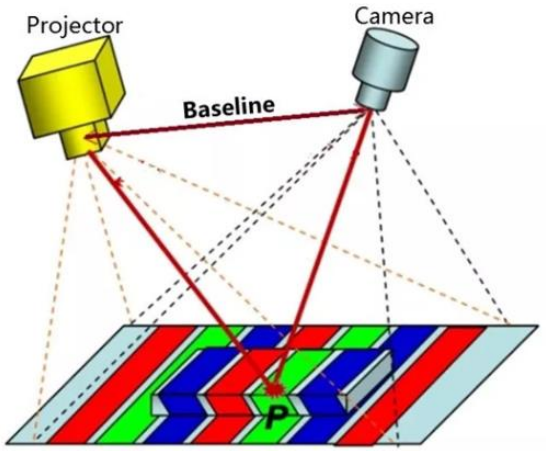


Hand

- **Accurate and Clear**

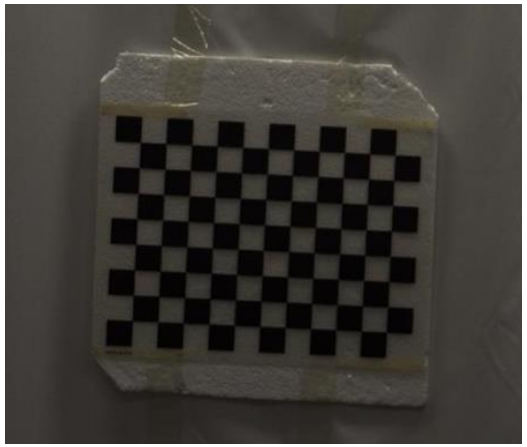
2. Research Content—Extraction of Key Points in Static Net

Camera Calibration

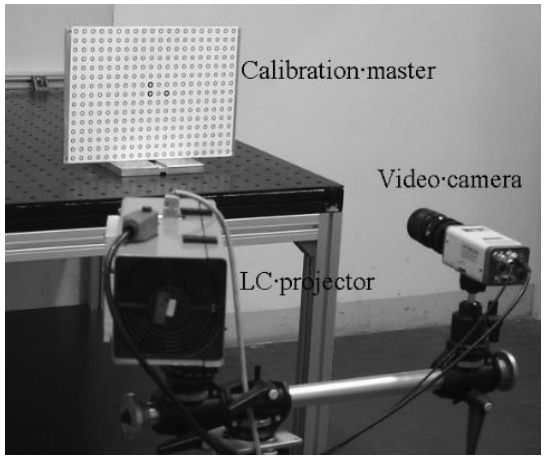


Structured Light Method

Projection Equipment Needed



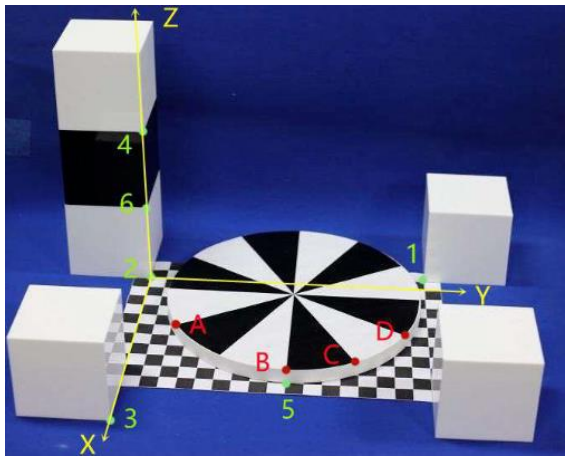
Checkerboard Calibration



Phase Measurement Calibration

Phase Decoding Required

- **High precision**
- **Simple operation**
- **Good robustness**

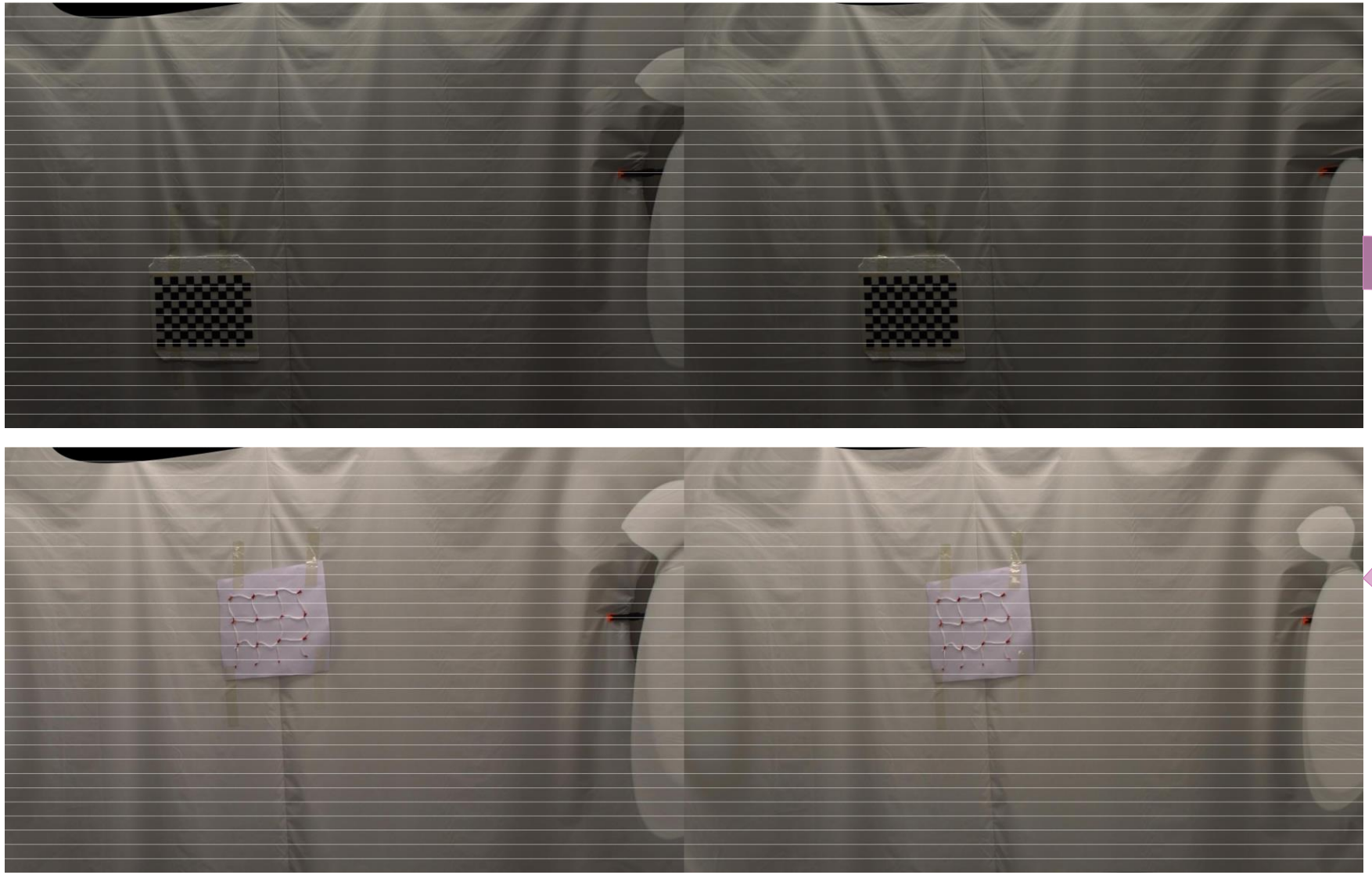


Three-dimensional Calibration Object

Three-dimensional Calibration Object Fabrication

2. Research Content—Extraction of Key Points in Static Net

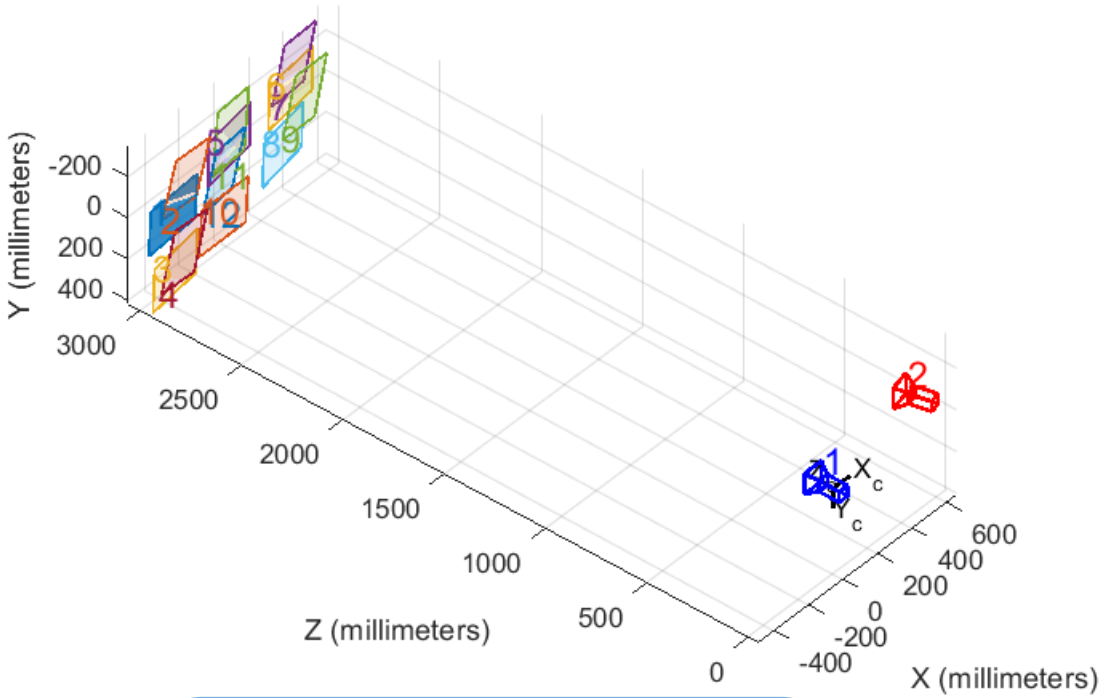
Camera Calibration Result Image

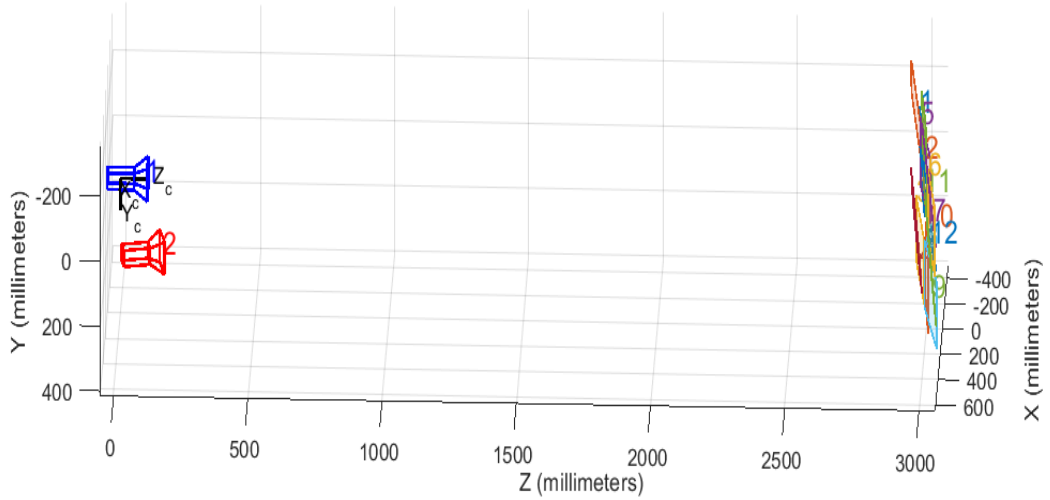


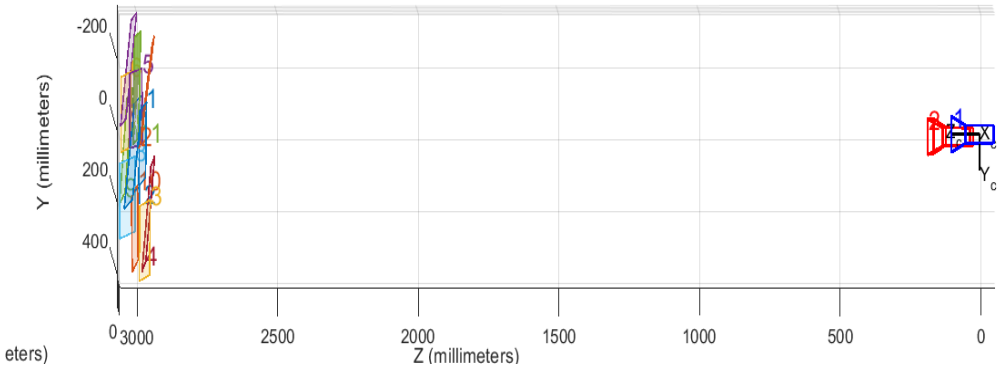
Align horizontally

2. Research Content—Extraction of Key Points in Static Net

Validation of Camera Calibration Results







compare the left View, the right View, and the top View with the actual scence data.

2. Research Content—Extraction of Key Points in Static Net

Camera Parameters

```
# 左相机内参矩阵
K_left = np.array([[1.98947506e+03, 0.00000000e+00, 9.72976686e+02],
                   [0.00000000e+00, 1.99483811e+03, 5.91592110e+02],
                   [0.00000000e+00, 0.00000000e+00, 1.00000000e+00]])

# 右相机内参矩阵
K_right = np.array([[1.98050314e+03, 0.00000000e+00, 9.75983368e+02],
                    [0.00000000e+00, 1.97975188e+03, 6.22379878e+02],
                    [0.00000000e+00, 0.00000000e+00, 1.00000000e+00]])

# 左相机到右相机的旋转矩阵和平移向量
R = np.array([[0.98348547, 0.0022631, 0.18097295],
              [-0.00326541, 0.99998094, 0.00524067],
              [-0.18095764, -0.00574507, 0.98347411]])

T = np.array([[-18.1609401],
              [-1.26707581],
              [-2.18217297]])
```

```
左相机投影矩阵 P_left:
 [[1.98947506e+03 0.00000000e+00 9.72976686e+02 0.00000000e+00]
 [0.00000000e+00 1.99483811e+03 5.91592110e+02 0.00000000e+00]
 [0.00000000e+00 0.00000000e+00 1.00000000e+00 0.00000000e+00]]

右相机投影矩阵 P_right:
 [[ 1.77118441e+03 -1.12501611e+00  1.31827187e+03 -3.80975634e+04]
 [-1.19089095e+02  1.97613853e+03  6.22469723e+02 -3.86663626e+03]
 [-1.80957640e-01 -5.74507000e-03  9.83474110e-01 -2.18217297e+00]]
```

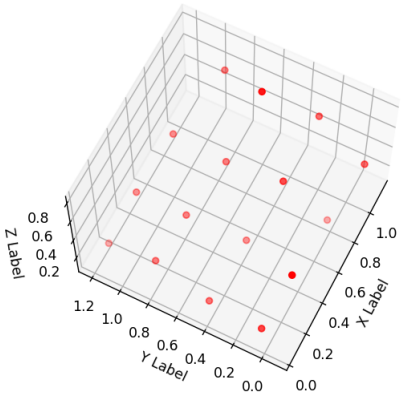
Using the intrinsic parameters of the left and right cameras and the formula $P=K[R\,|\,t]$, calculate the projection matrices for the left and right cameras.

2. Research Content—Static Net Surface Structure Reconstruction

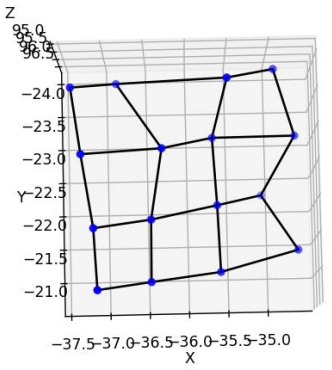
Key Point Matching

Matching Left and Right Points Based on Descriptors

Three-dimensional Point Reconstruction



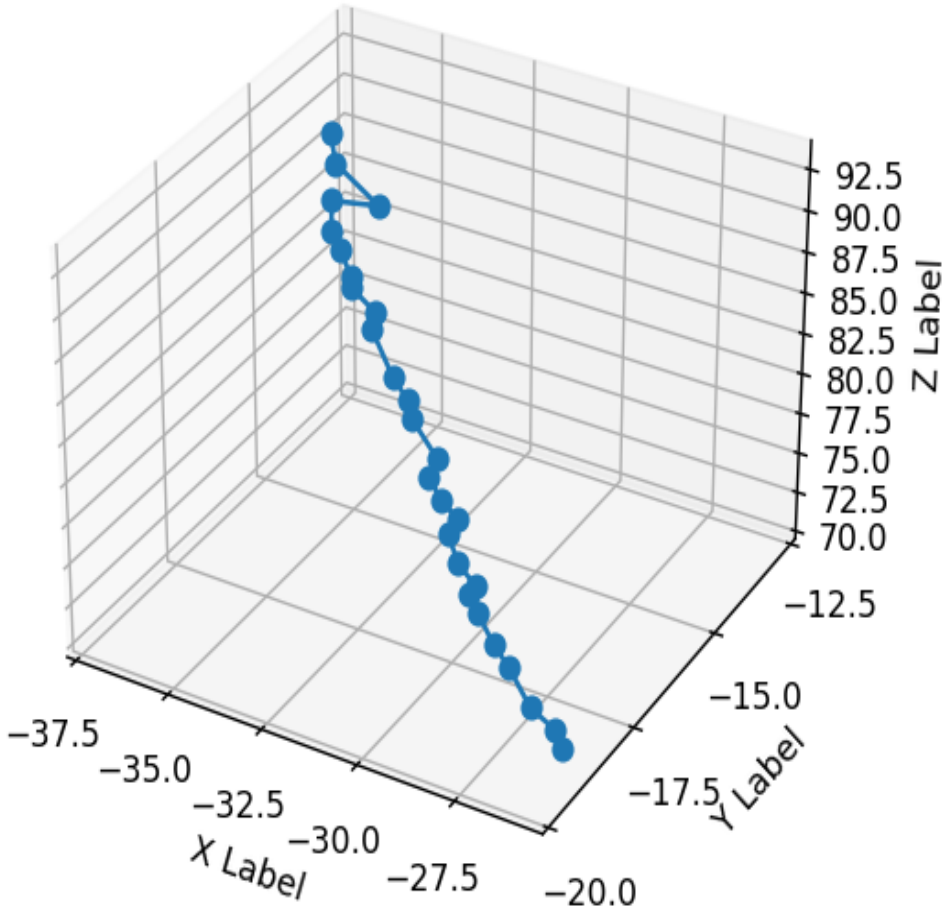
Three-dimensional Point Surface Structure Reconstruction



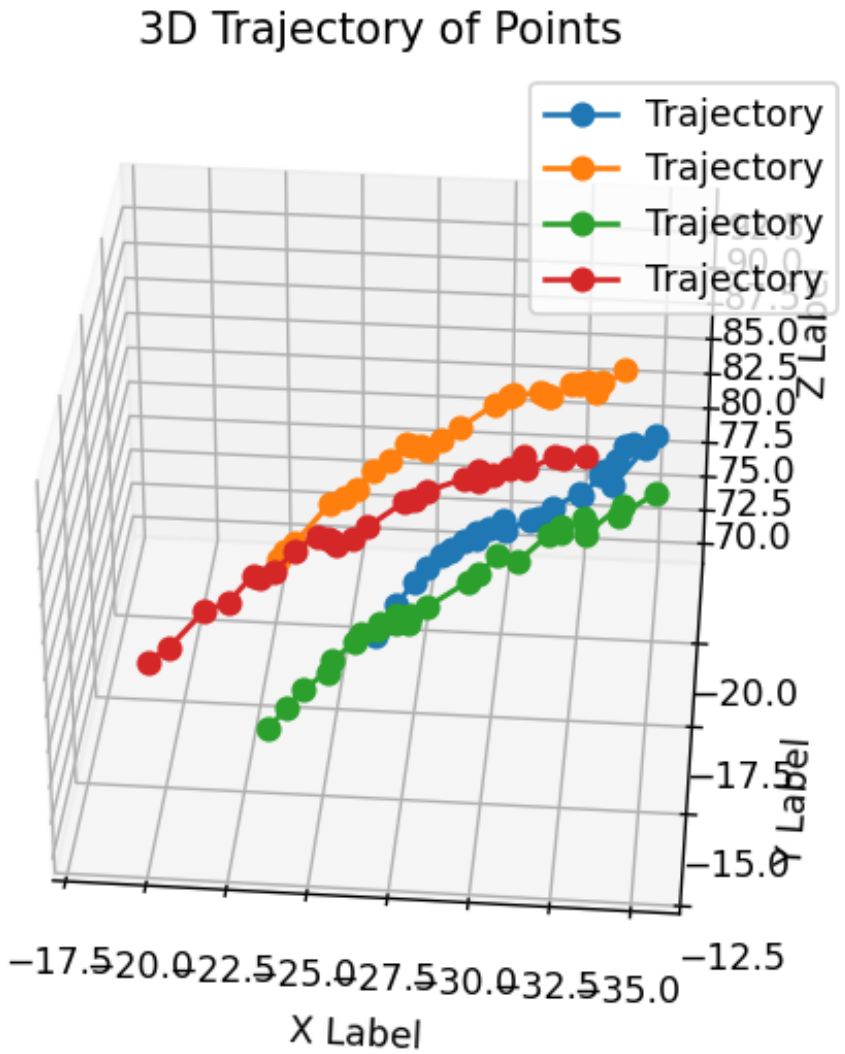
2. Research Content—Reconstruction of Key Point Trajectories in Dynamic Net

Left and right cameras capture the motion process separately, and dynamic reconstruction is based on static reconstruction.

2. Research Content—Reconstruction of Key Point Trajectories in Dynamic Net

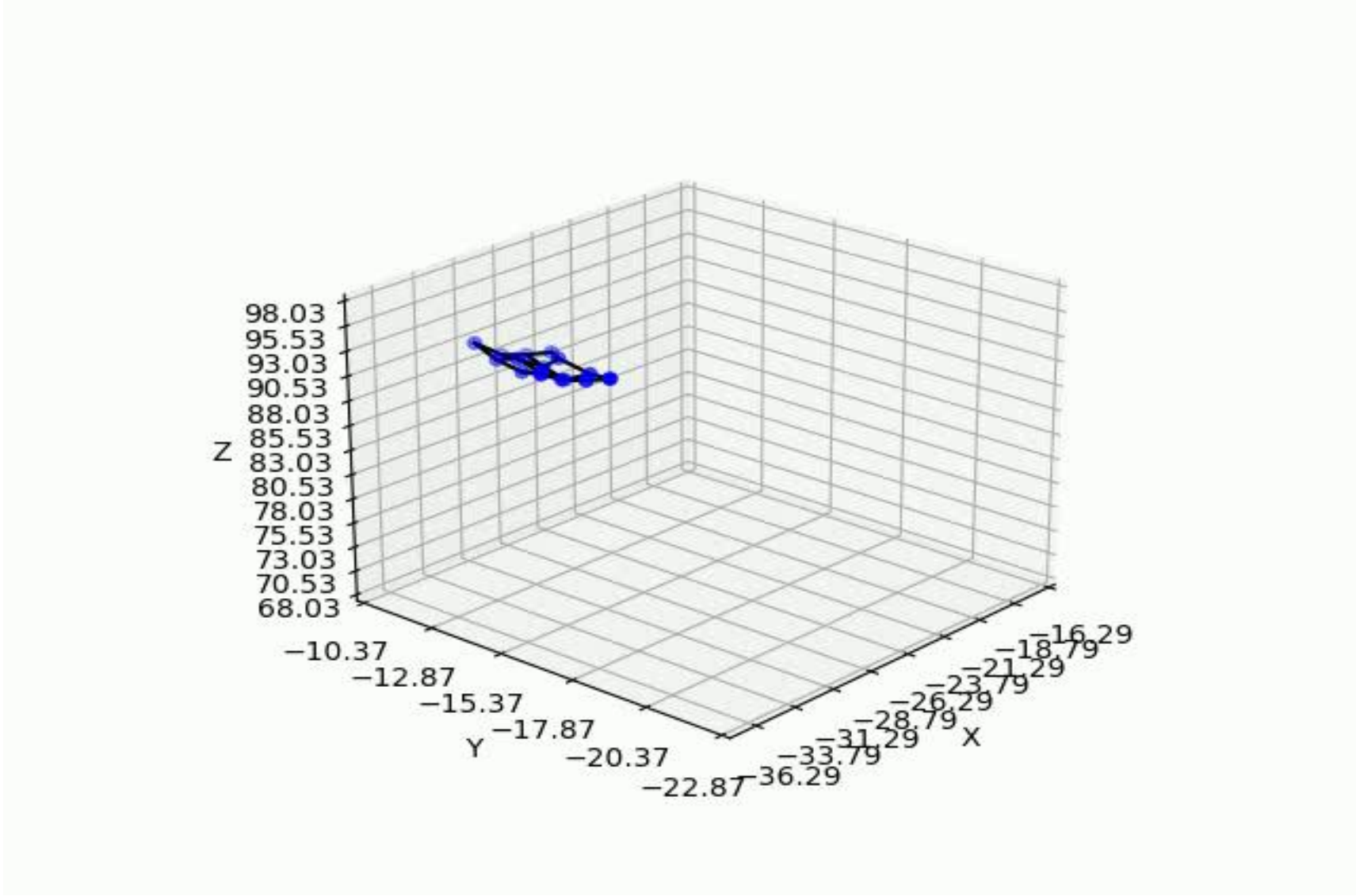


Single Point Motion Trajectory

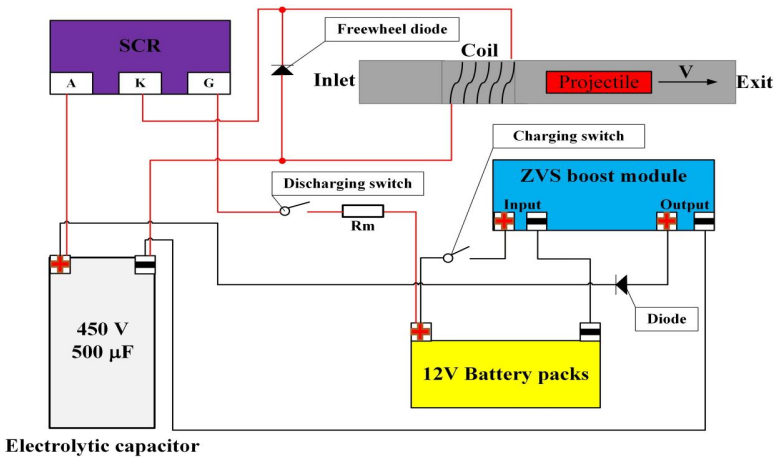


Overall Motion Trajectory of Four Corner Points

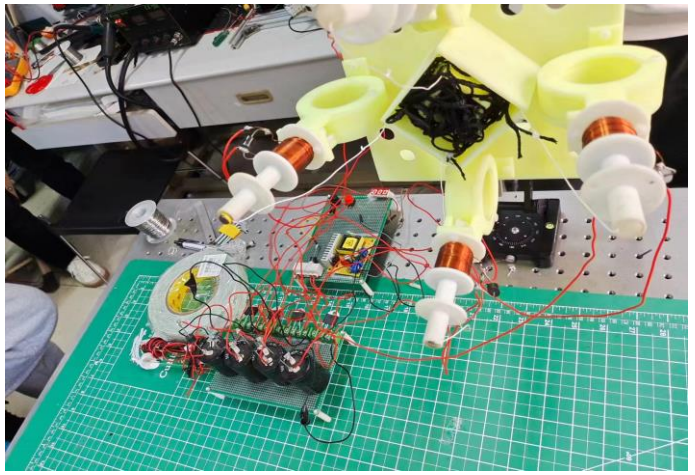
2. Research Content—Dynamic Surface Structure Reconstruction of Net



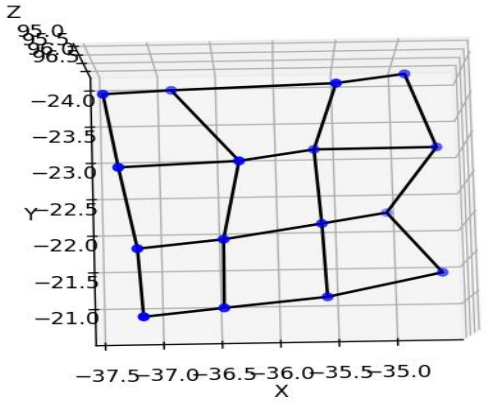
3. Innovative Aspects of the Content



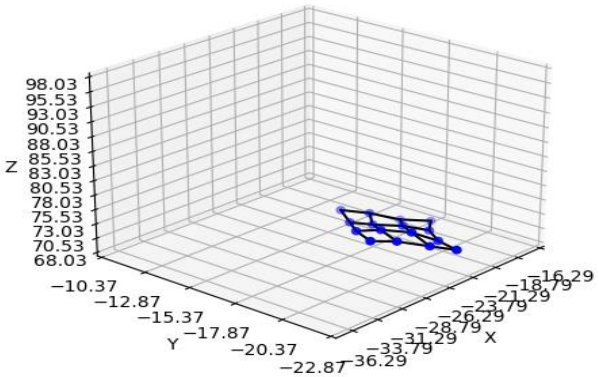
Electromagnetic Dynamics Modeling



Development of Launcher Prototype

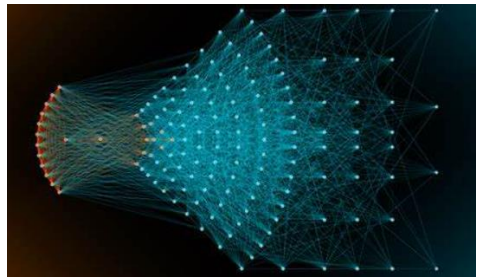


Static Reconstruction of Net

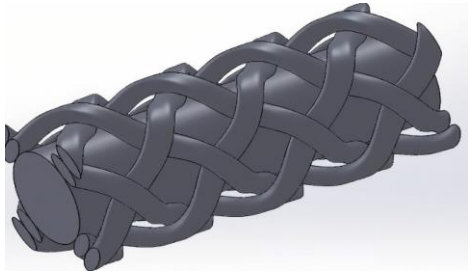


Dynamic Reconstruction of Net

4. Research Outlook



Utilizing Neural Networks to Identify Key Points



Refinement of Three-Dimensional Model Establishment

Theoretical Innovation in Algorithm and Dynamics

THANKS

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