Evaluation of Quadratic Surface Descriptors for Computational Reassembling of Archaeological Artifacts

Udomchai Techavipoo,
Sanparith Marukatat,
Thitiporn Chanwimaluang

Main Goal

- Digitally reconstruct archaeological artifacts

*Taken from A.R. Will, D.B. Cooper. Computational Reconstruction of Ancient Artifacts. IEEE Signal Processing Magazine. 2008;25:65-83.

Significants

- Help archaeologists reassemble fragments of relics.
- Benefit the studies of the original shapes, craftsmanship, and creativity of our ancestors.
- Possibly apply the descriptors to other fields, e.g., shape-based molecular similarity searching.

Outline

- Quadratic Surface Descriptors
- Materials and Methods
- Results
- Conclusions

Quadratic Surface Descriptors

- A set of parameters estimated from a quadratic equation to represent a surface.
- It is rotational invariance.

<u>To find QSD</u>

- Select a vertex on a surface.
- Define its neighboring vertices.

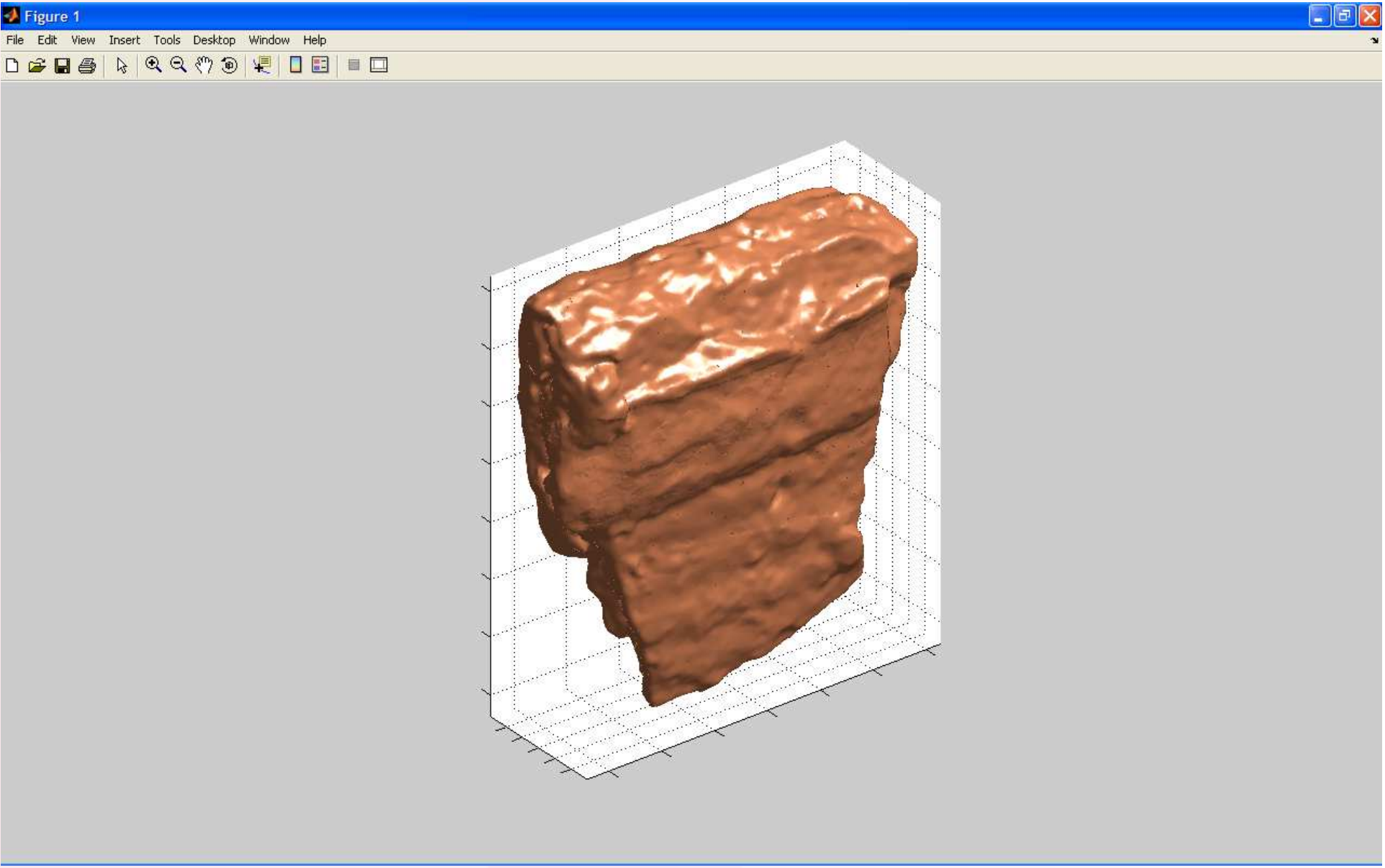


Figure 1
File Edit View Insert Tools Desktop Window Help

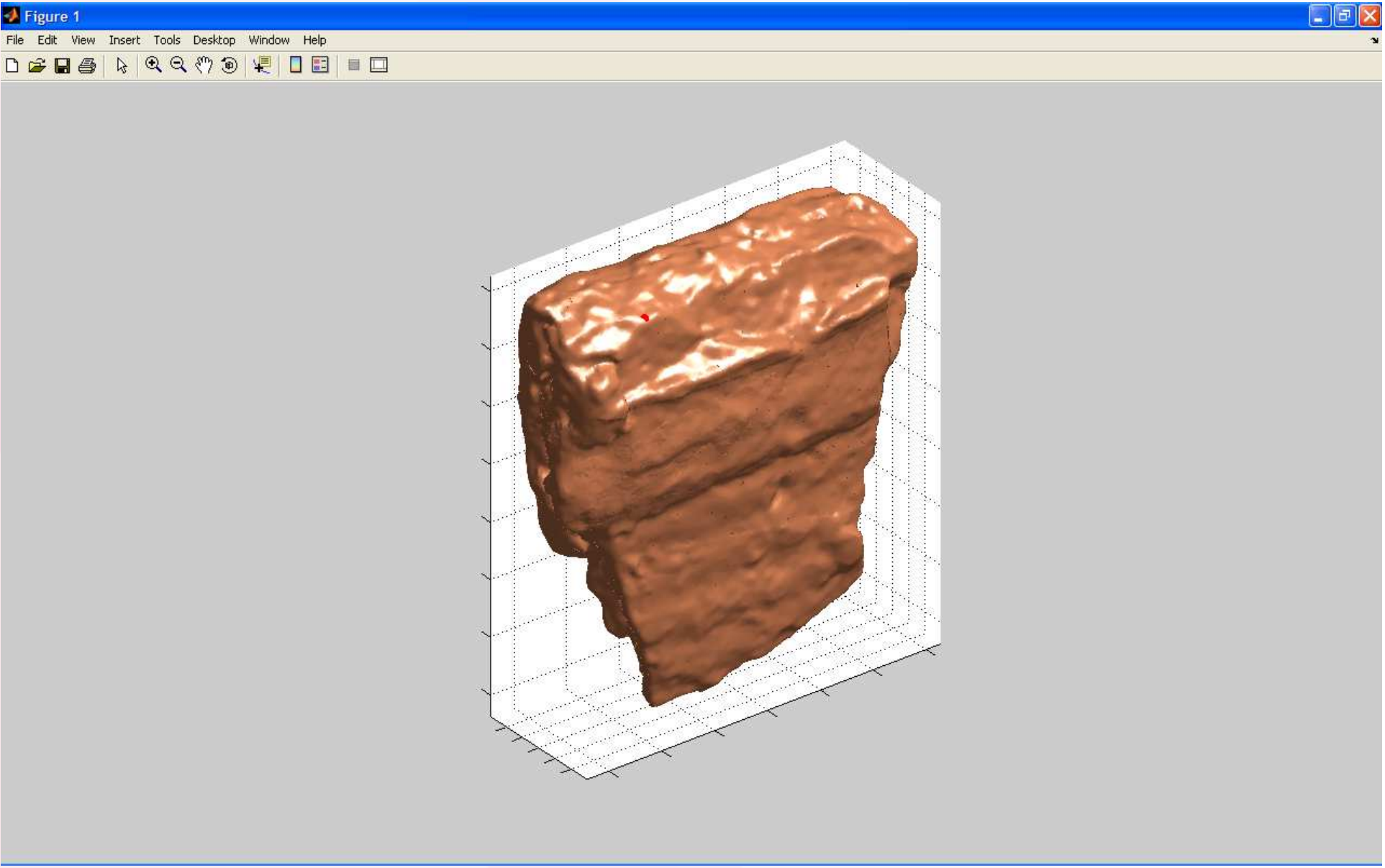


Figure 1
File Edit View Insert Tools Desktop Window Help

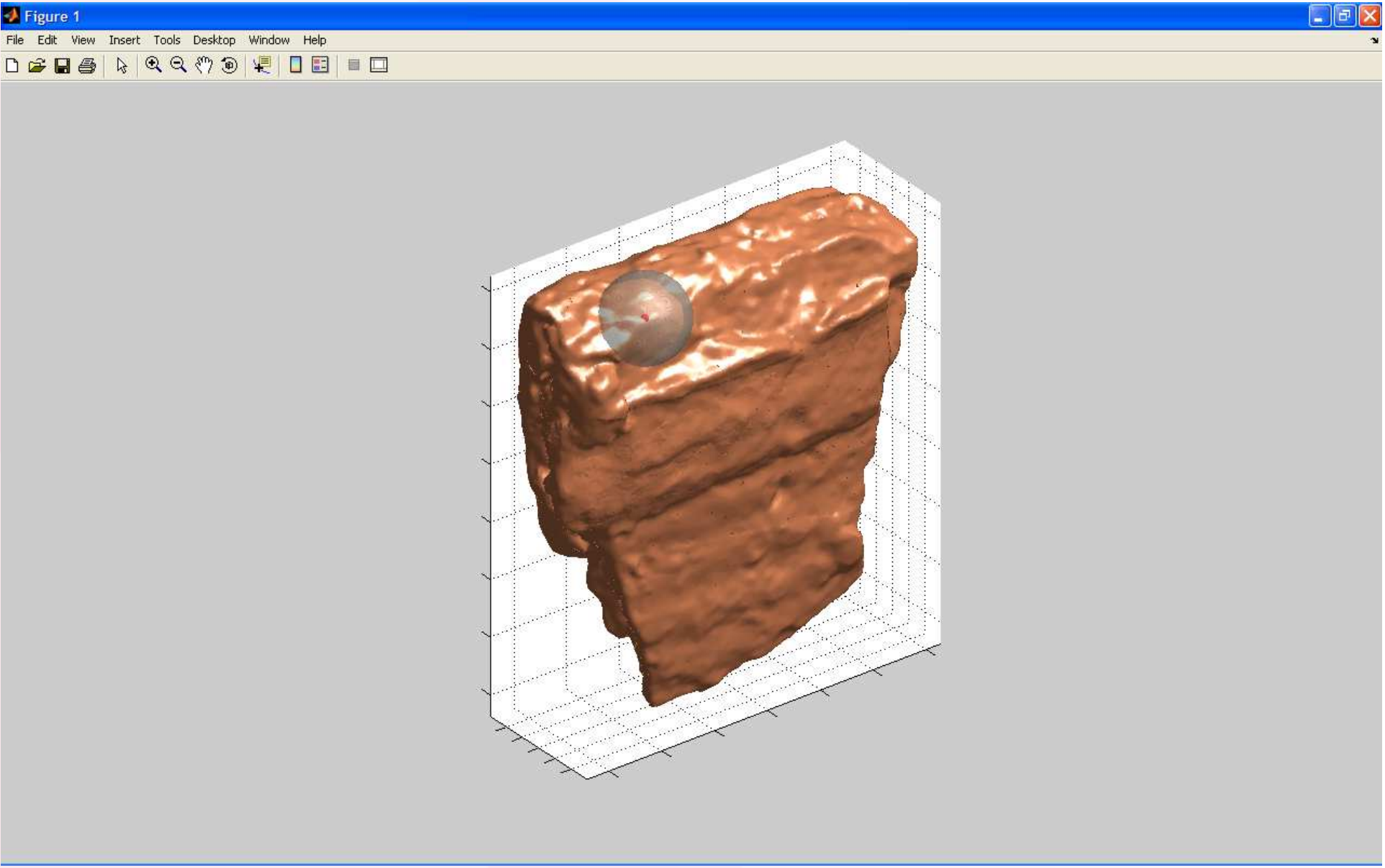


Figure 1
File Edit View Insert Tools Desktop Window Help

Quadratic Surface Descriptors

- Create a local coordinate system (u,v,w) using
  - Eigen decomposition of the covariance matrix of the selected coordinates or
  - Fitting a plane passing through the central vertex to minimize the mean squared error.
- Project the selected vertices onto the local coordinate.

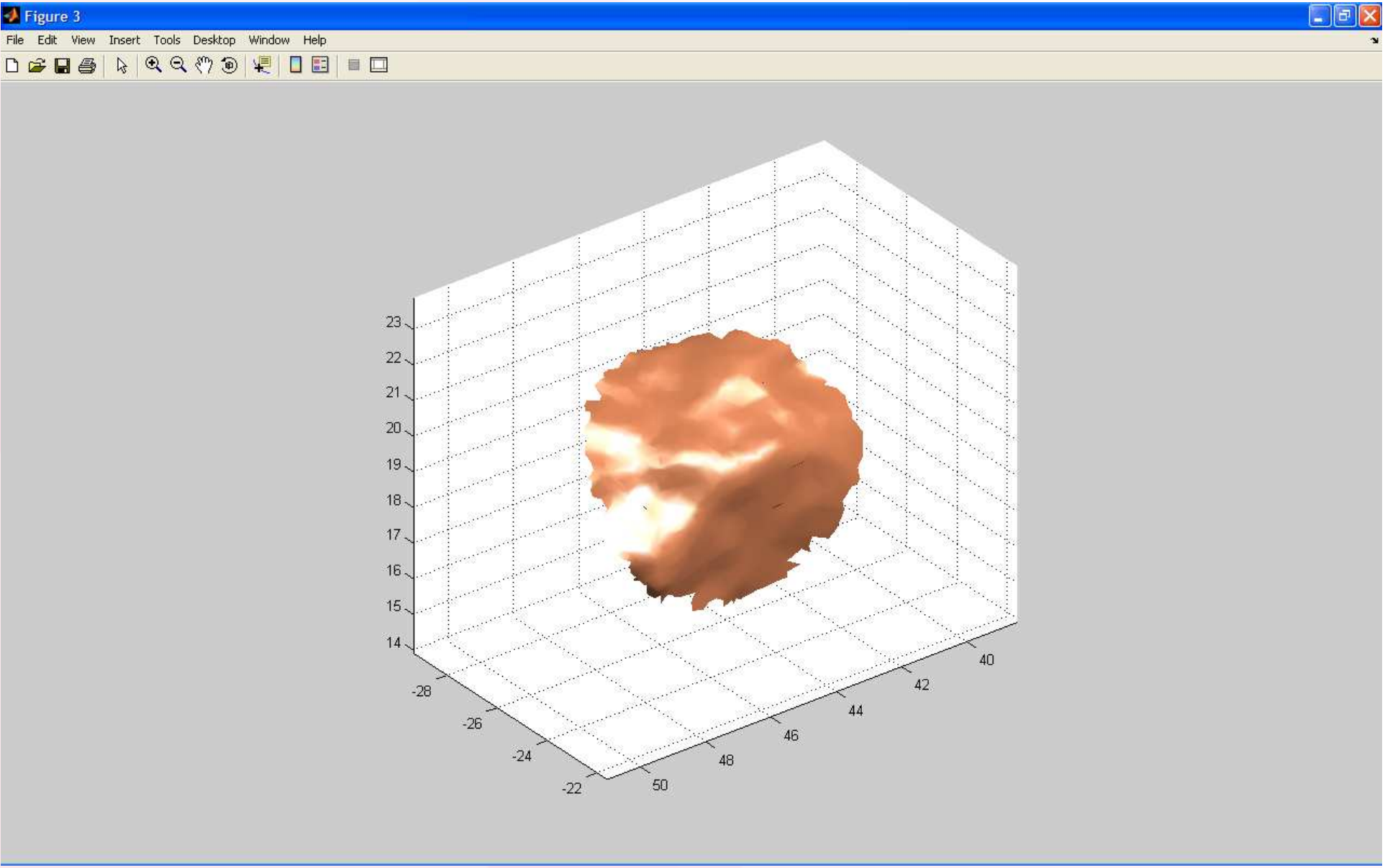


Figure 3
File Edit View Insert Tools Desktop Window Help
23
22
21
20
19
18
17
16
15
14
-28
-26
-24
-22
50
48
46
44
42
40

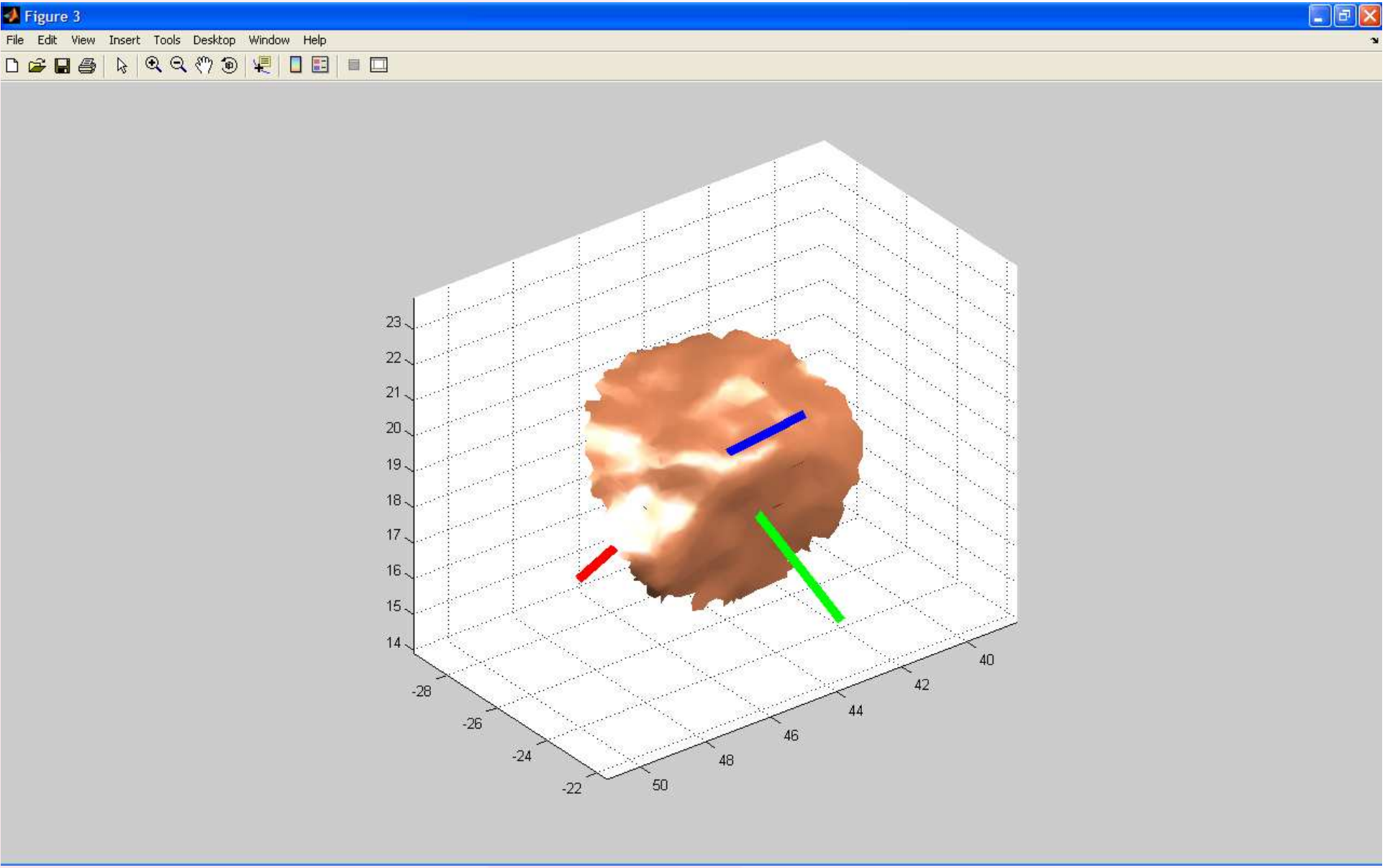


Figure 3
File Edit View Insert Tools Desktop Window Help
23
22
21
20
19
18
17
16
15
14
-28
-26
-24
-22
50
48
46
44
42
40

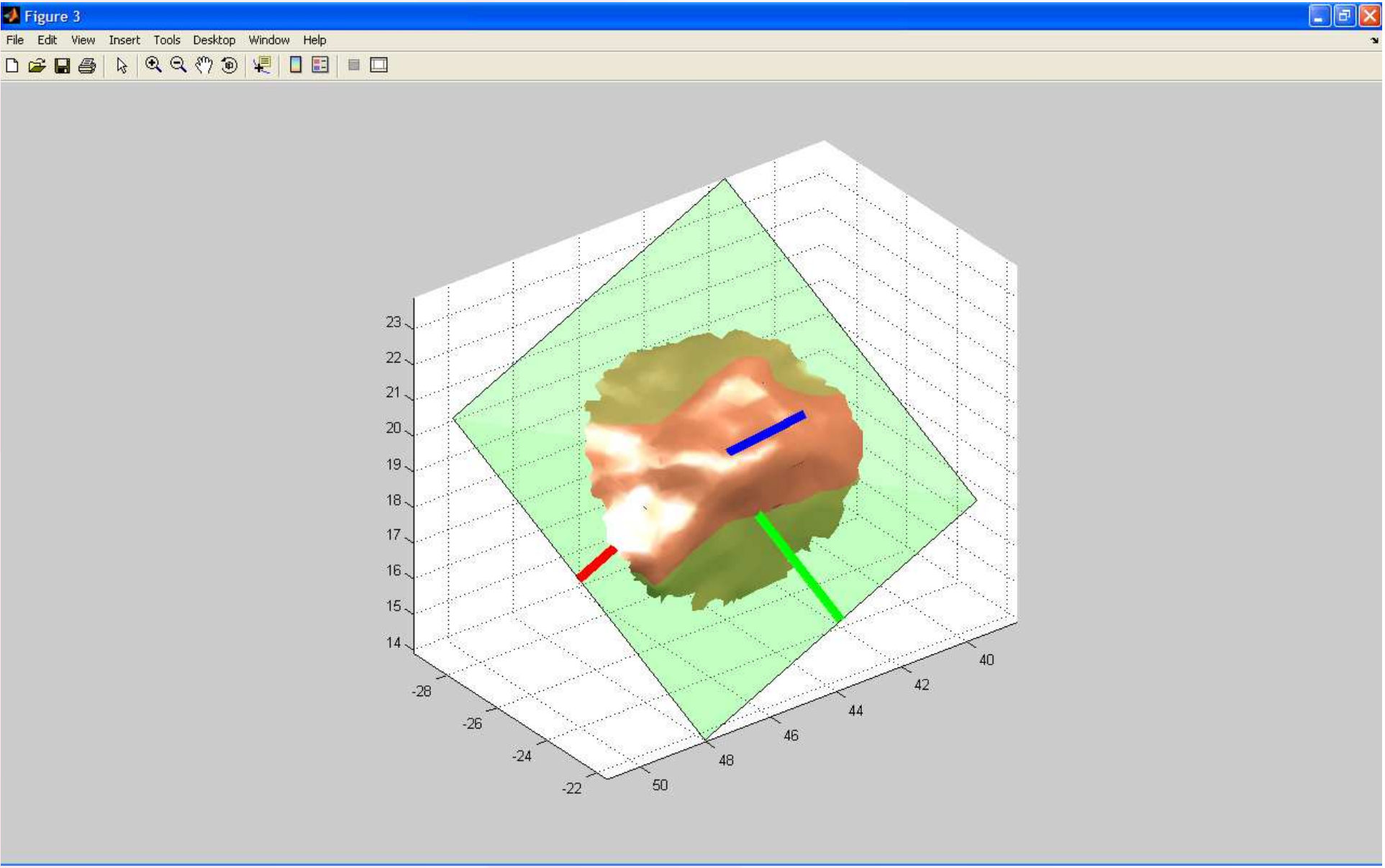


Figure 3
File Edit View Insert Tools Desktop Window Help
23
22
21
20
19
18
17
16
15
14
-28
-26
-24
-22
50
48
46
44
42
40

Quadratic Surface Descriptors

- Fit the surface with quadratic eq, i.e., $w = f(u,v) = Au^2 + Buv + Cv^2$.
- Estimate A, B, and C using LSE.
- Find Hessian matrix (H) from A, B, and C
  - $H = [\partial^2 w/\partial u^2, \partial^2 w/\partial u \partial v; \partial^2 w/\partial v \partial u, \partial^2 w/\partial v^2]$.
  - $H = [2A, B; B, 2C]$.
- Eigen decomposes H to get $\lambda = (\lambda 1, \lambda 2)$, where is the eigenvalues $\lambda 1 > \lambda 2$.

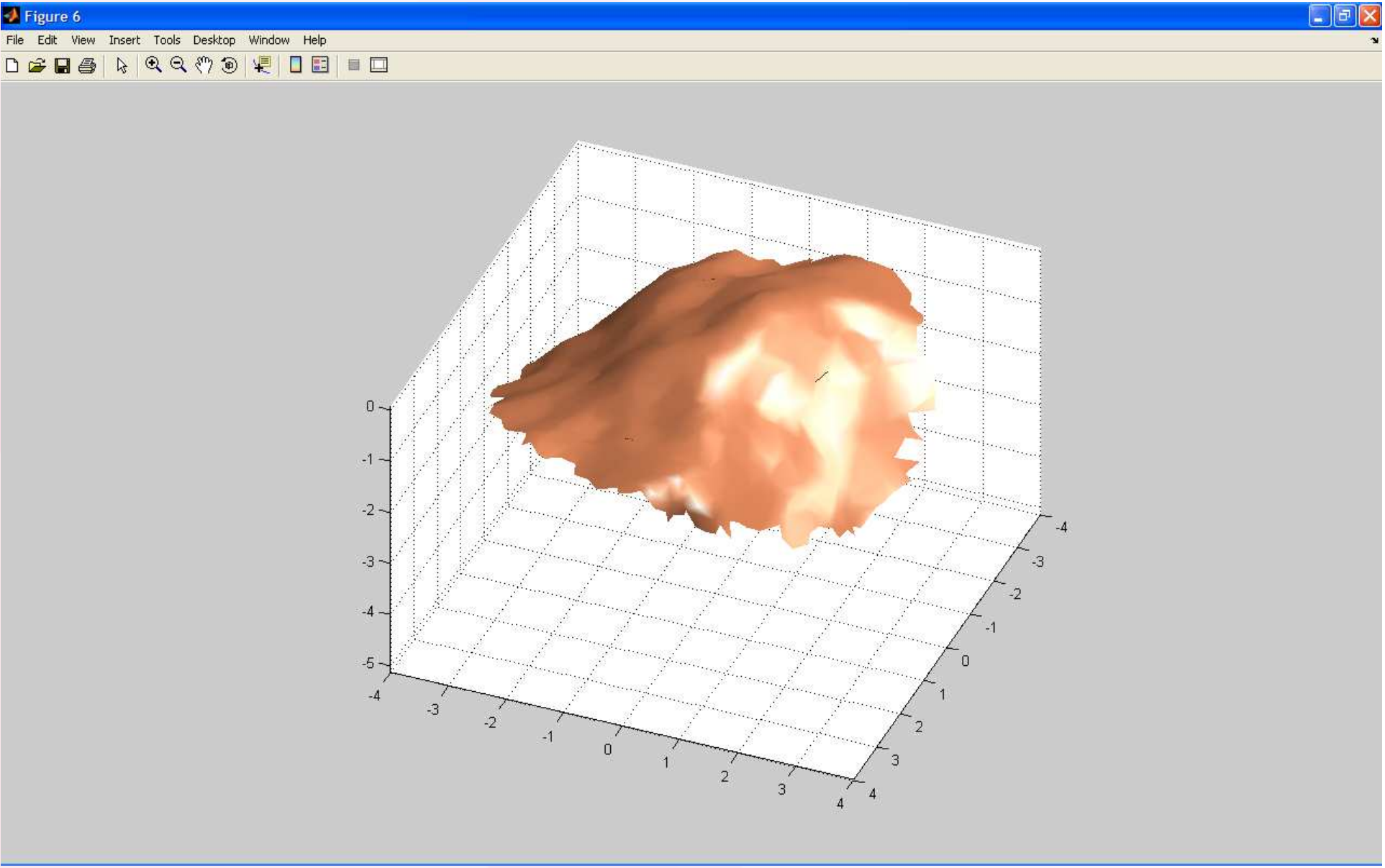


Figure 6
File Edit View Insert Tools Desktop Window Help
0
-1
-2
-3
-4
-5
-4 -3 -2 -1 0 1 2 3 4
-4 -3 -2 -1 0 1 2 3 4

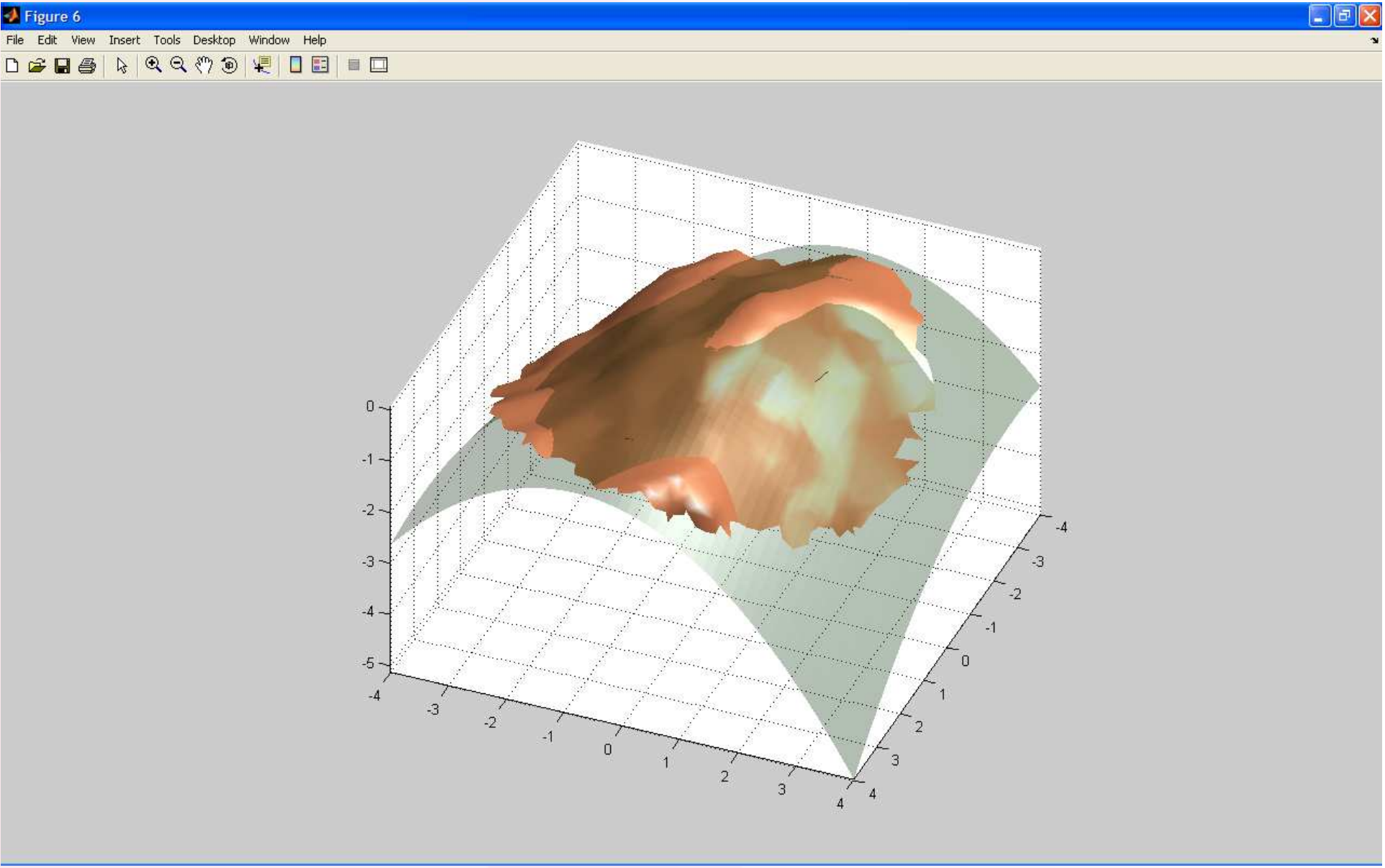


Figure 6
File Edit View Insert Tools Desktop Window Help
0
-1
-2
-3
-4
-5
-4 -3 -2 -1 0 1 2 3 4
-4 -3 -2 -1 0 1 2 3 4

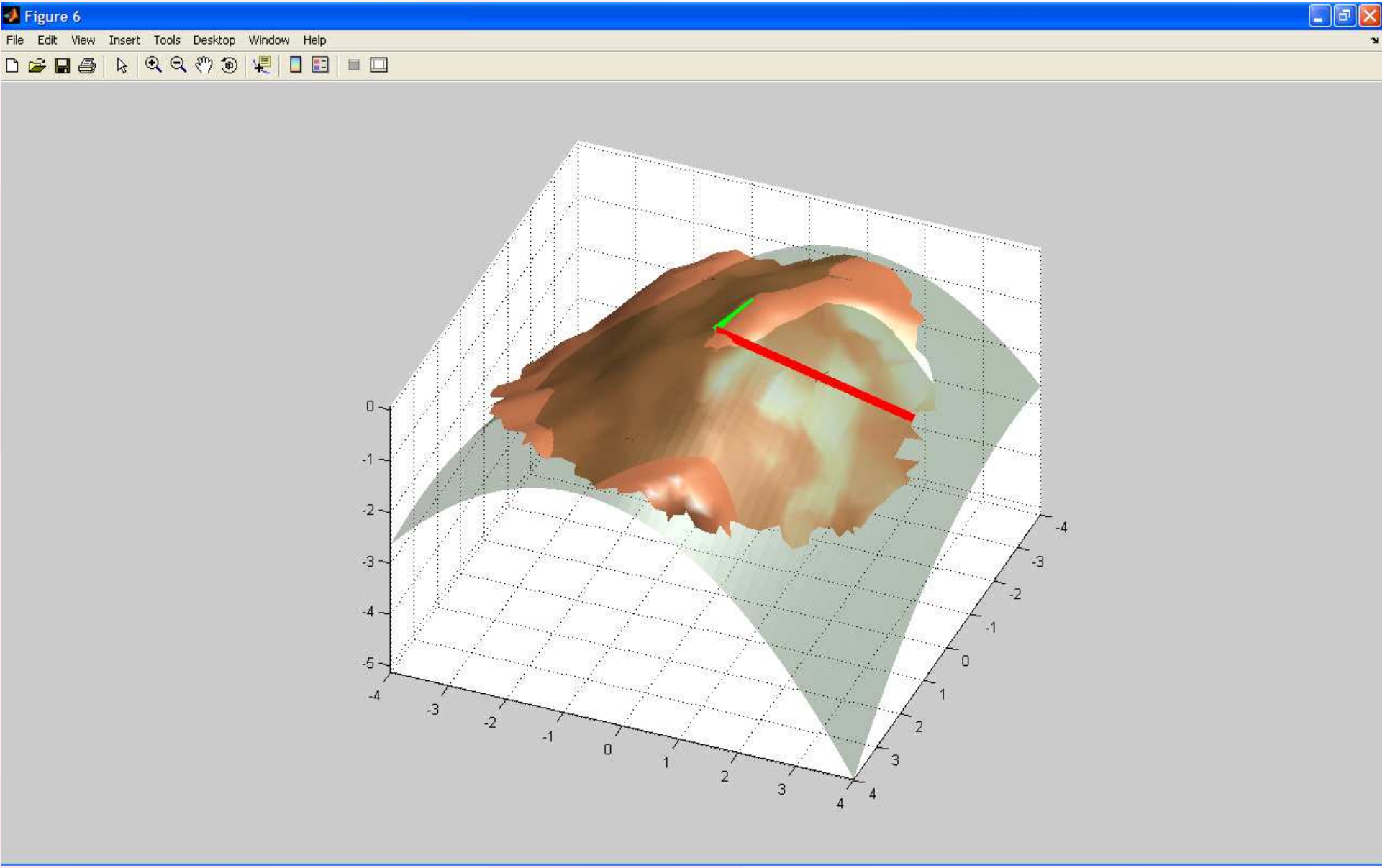
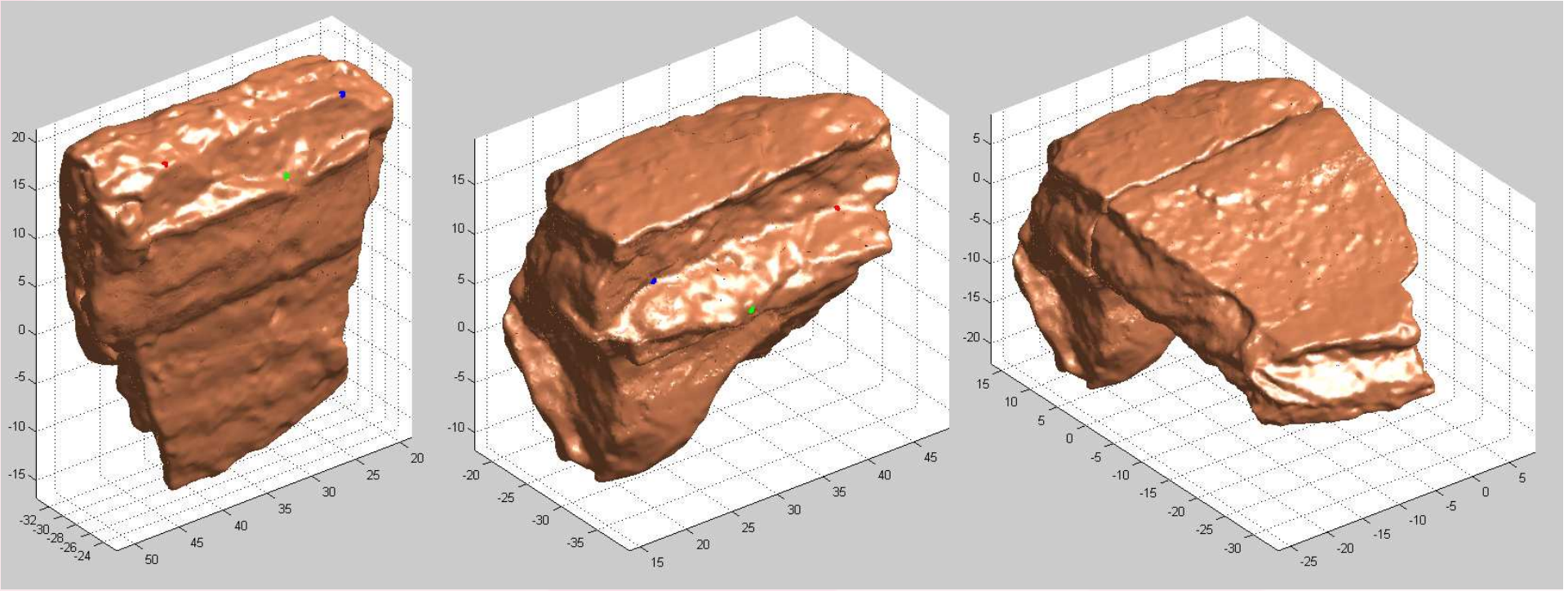


Figure 6
File Edit View Insert Tools Desktop Window Help
0
-1
-2
-3
-4
-5
-4 -3 -2 -1 0 1 2 3 4
-4 -3 -2 -1 0 1 2 3 4

Materials and Methods

- Scan 2 objects using a 3D optical scanner.
- Manually find best corresponding vertices on object 1 (V1) to the vertices on object 2 (V2) for reference.
- Find QSD of the matched vertices on V1 and all vertices on V2.
- Find a top-100 list of candidates in V2 for each vertex in V1 ordered ascendingly using Euclidean distance of QSD.
- Measure the matching success rate, where success if $|v1-v2|<0.5mm$, for a $v1 \in V1$ and any $v2 \in$ the top-100 list.
- Limit the vertices using MSE of the quadratic surface fitting, $MSE(V2) < 1.2*MSE(v1)$ and $MSE(V1) < \{0.2,0.1,0.05\}$.

Materials and Methods

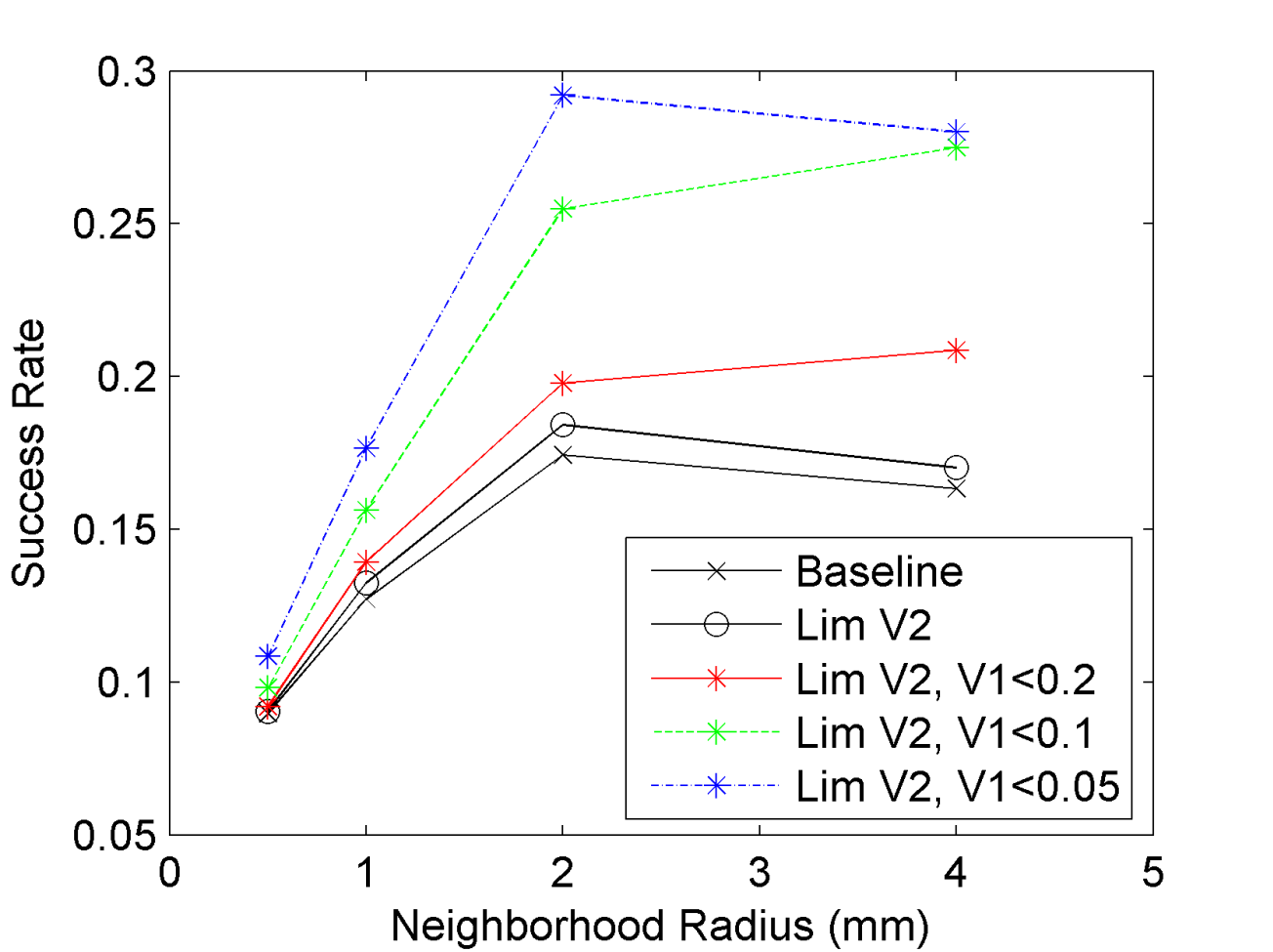


Object 1

Object 2

Manually reconstructed
Object 1 and Object 2

Results


0.3
0.25
0.2
0.15
0.1
0.05
Success Rate
0
1
2
3
4
5
Neighborhood Radius (mm)
Baseline
Lim V2
Lim V2, V1<0.2
Lim V2, V1<0.1
Lim V2, V1<0.05

Conclusions

- Matching success rate can be improved using MSE of the quadratic surface fitting.
- Larger local neighbors seem to provide better success rate.
- However, the success rate using this method still low (~1/3).
- Limitations: Only 2 objects used and no ground truth.