한국전자통신연구원
Electronics and Telecommunications Research Institute

# Sketch-based Terrain Modeling

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**Next-generation Visual Research Division**
**ETRI**

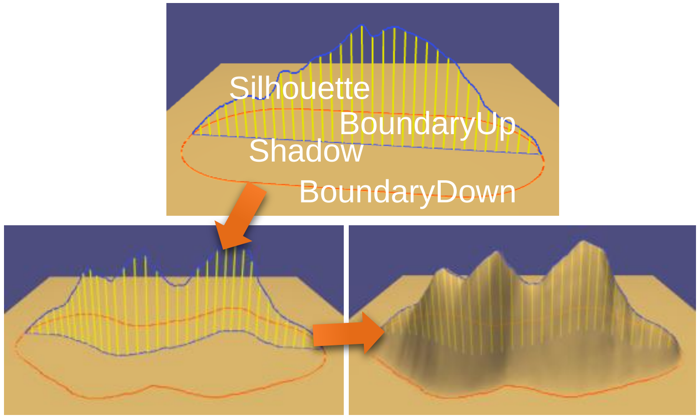
# Outline

- Known Methods
  - Landform Sketching
  - Terrain Synthesis
- New Methods
  - Landform Composition
  - Land-Outline Sketching
- Special Research
  - RBF-based Terrain Modeling

# Known methods

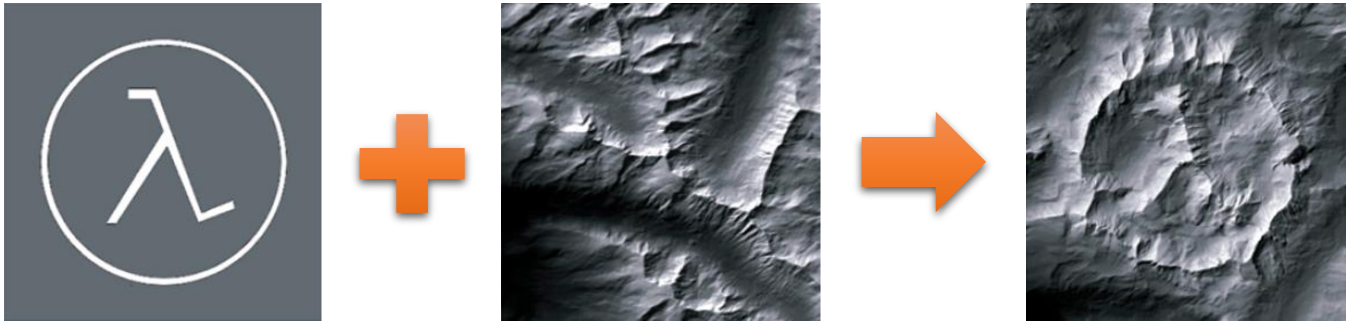
## Landform Sketching

**A set of sketch lines**




## Terrain Synthesis

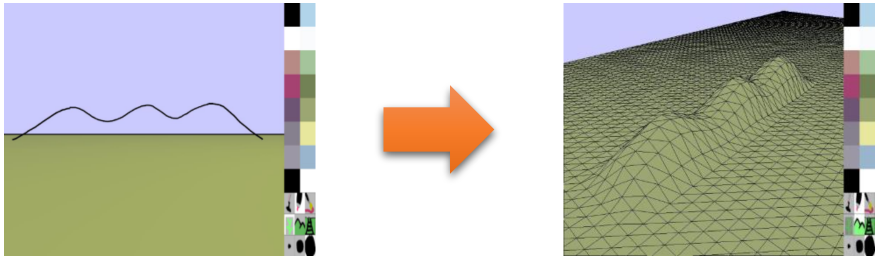
**A sketch line + patch comp.**



# Previous Works of Landform Sketching

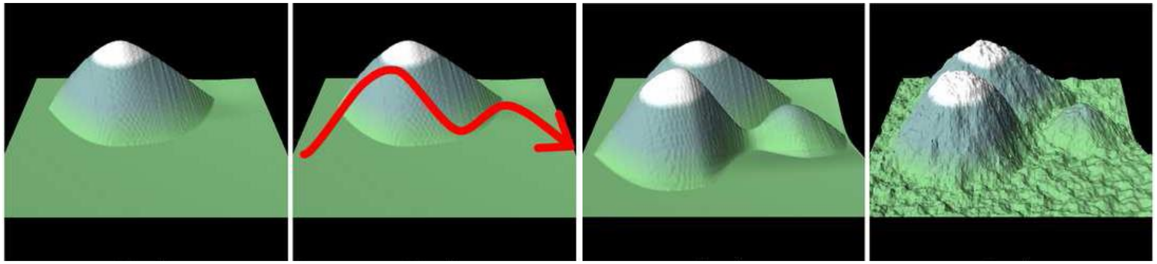
## Harold: A World Made of Drawings(2000)

**Only Silhouette line**



## A Sketching Interface for Terrain Modeling(2004)

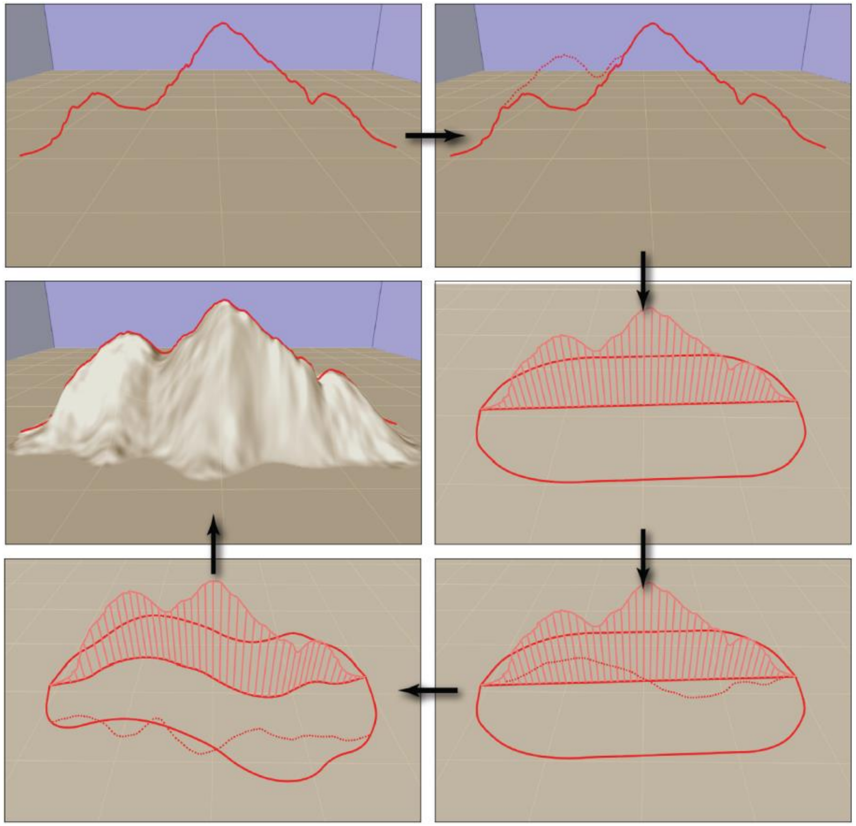
**Boundary lines and Noise**



# Landform Sketching (1)

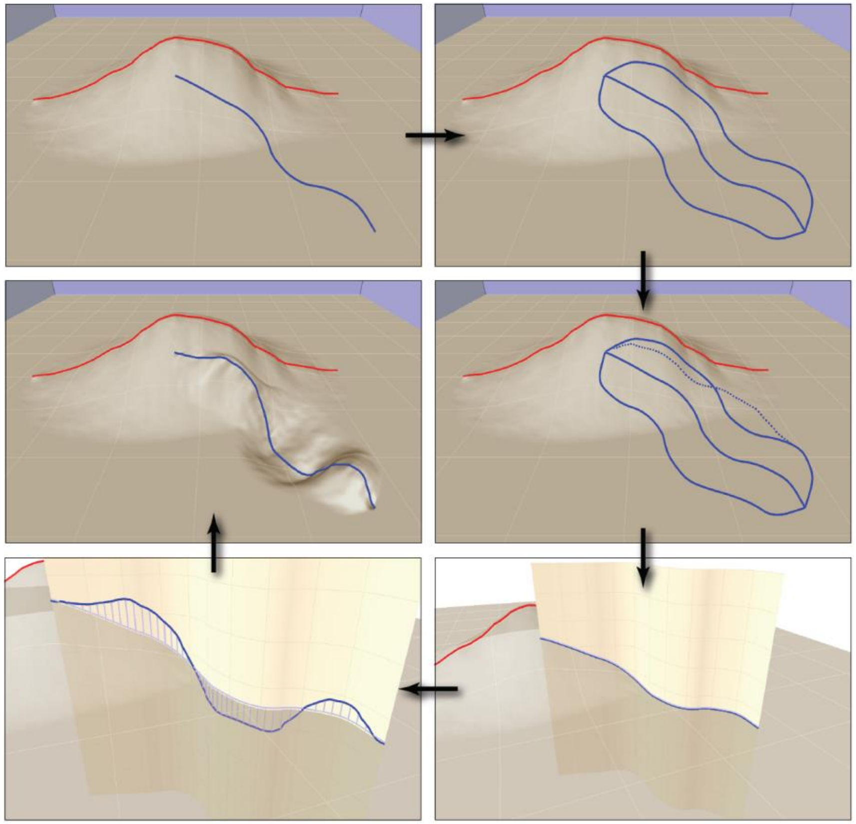
## Terrain Sketching(2009)

## Silhouette Line Sketching First



# Landform Sketching (2)

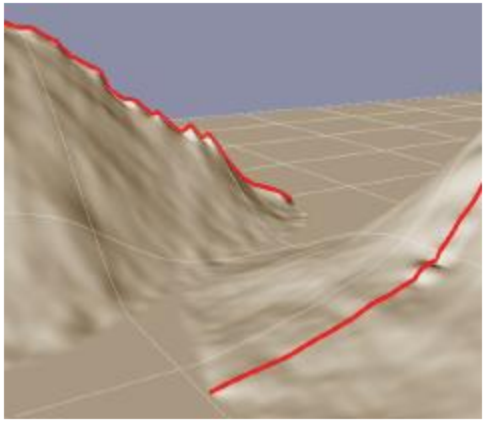
## Shadow Line Sketching First



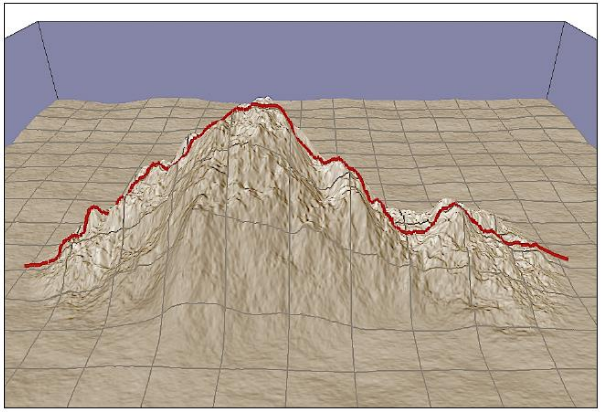
# Landform Sketching (3)

## Multi-resolution Deformation and Noise Propagation

**Low**

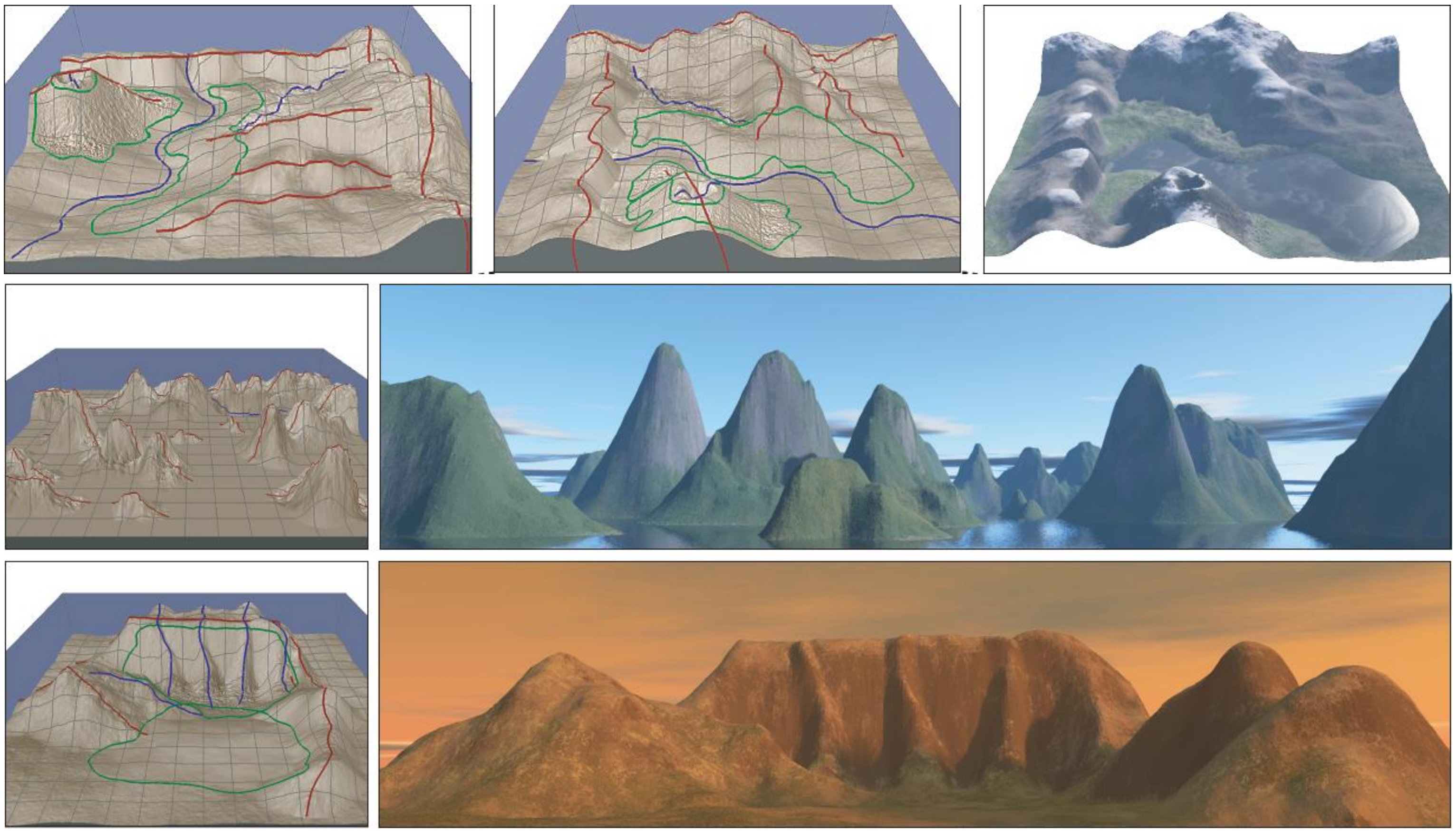


**High**



# Landform Sketching (4)

## Results



# Landform Sketching (5)

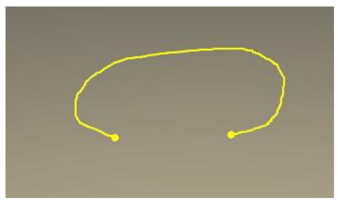
## Data Format

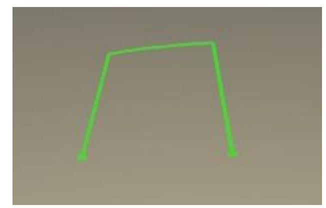
```
#Header
dHeightMap [sPathFile] [nRows] [nColumns]; the reference Height Map
nLandforms [n]

#Landform 0
nPoints [n]; number of points of all sketch lines except BP and EP
vBP [fX] [fY] [fZ]; the begin point of all sketch lines
vEP [fX] [fY] [fZ] ; the end point of all sketch lines
avSI { [fX] [fY] [fZ], … }; the silhouette sketch line
avSH { [fX] [fY] [fZ], … } ; the shadow sketch line
avBD { [fX] [fY] [fZ], … } ; the boundary down sketch line
avBU { [fX] [fY] [fZ], … } ; the boundary up sketch line
aiParents [n] { [i] }; index list of parent landforms
aiChildren [n] { [i] } ; index list of children landforms

#Landform 1
…
```

# Landform Sketching (6)

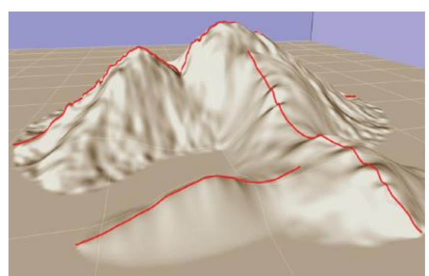
## Analysis

**All points of sketch lines must be in between begin and end point**





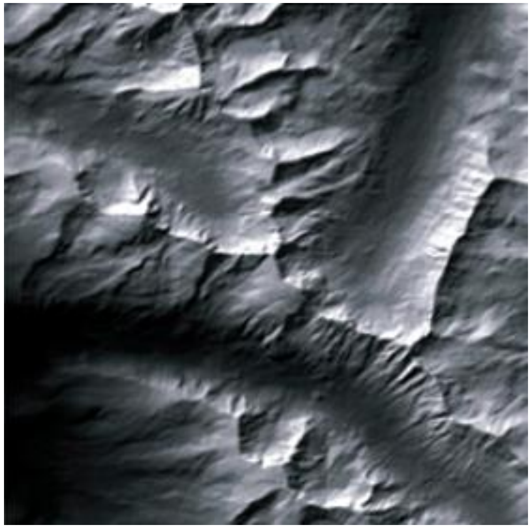
**It is very difficult to combine 3D landforms for a complex terrain**



# Terrain Synthesis (1)

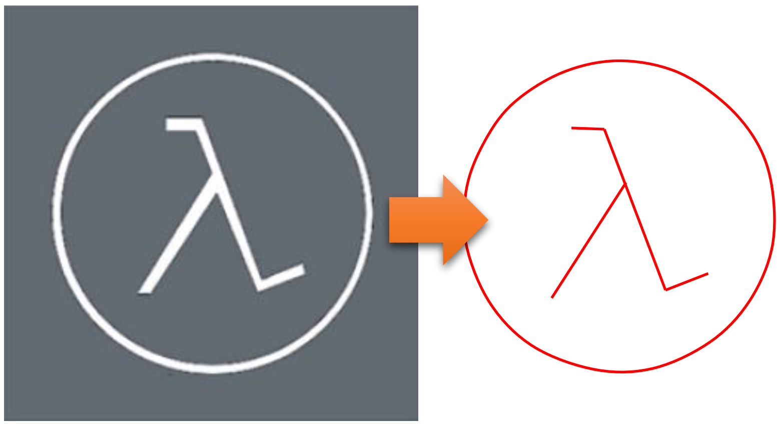
## Terrain Synthesis from DEM (2007)

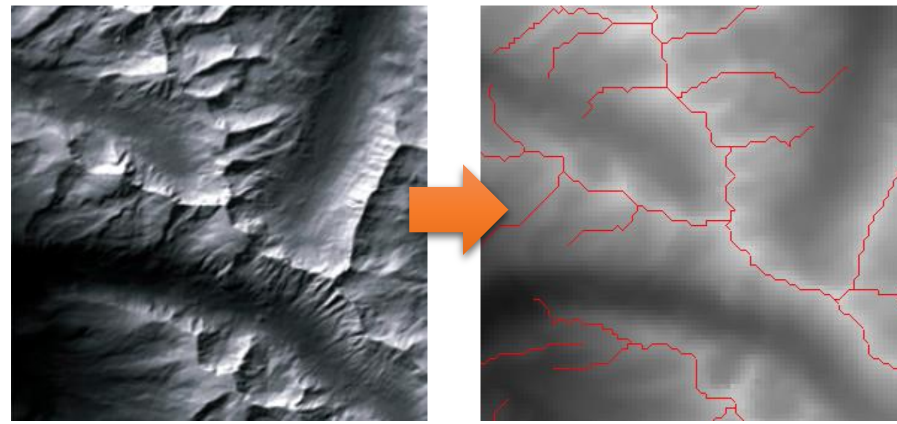
**Sketch Image Input** | **DEM Image Input**



# Terrain Synthesis (2)

## Feature Line Extraction

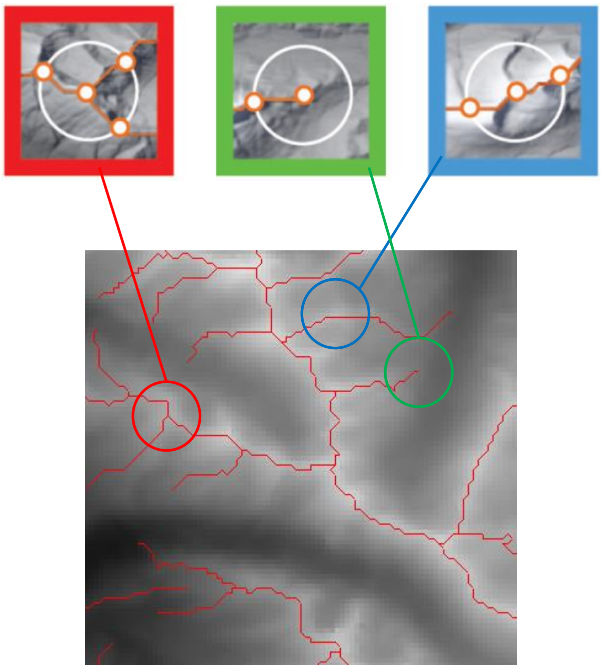


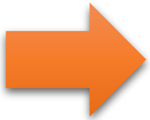


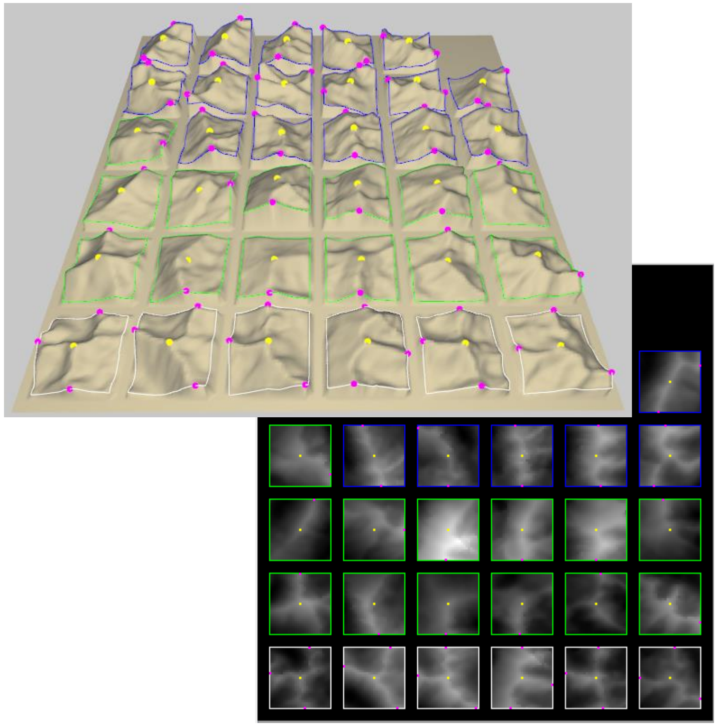
**Profile Recognition and Polygon-Breaking Algorithm(PPA)**

# Terrain Synthesis (3)

## Feature-based Patch Extraction

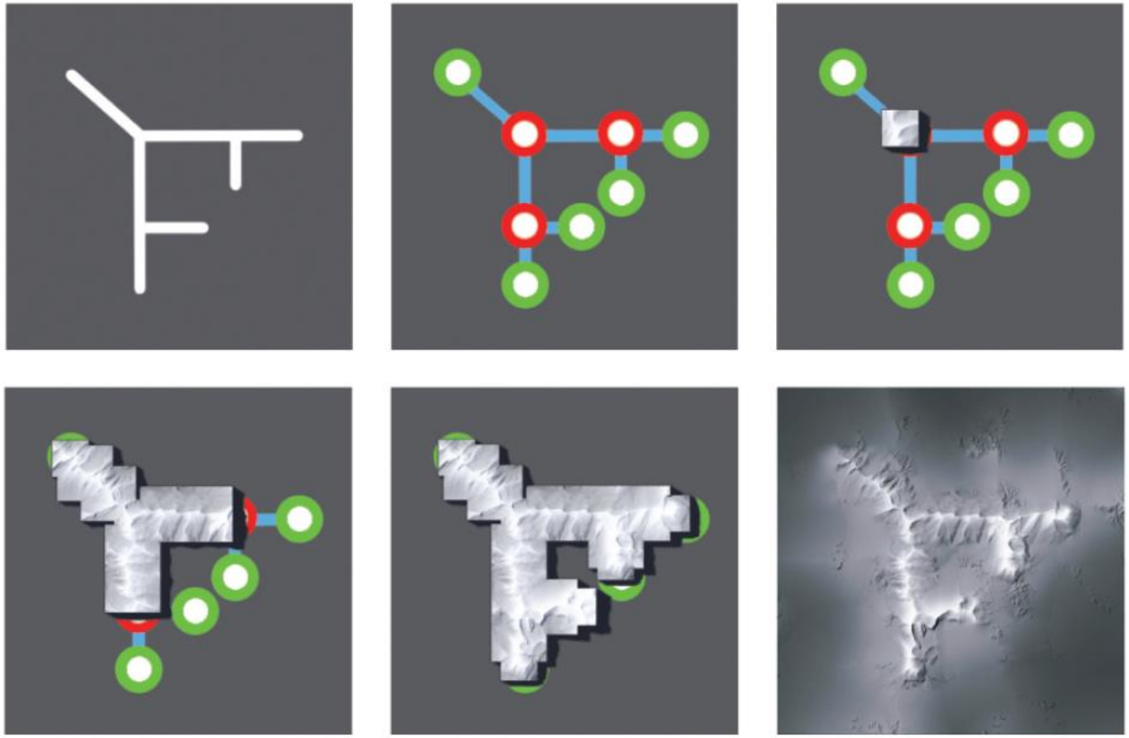






# Terrain Synthesis (4)

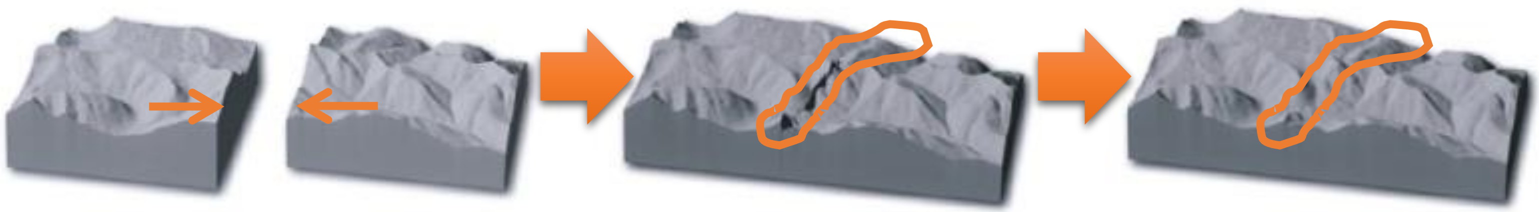
## Feature Patch Matching and Placement

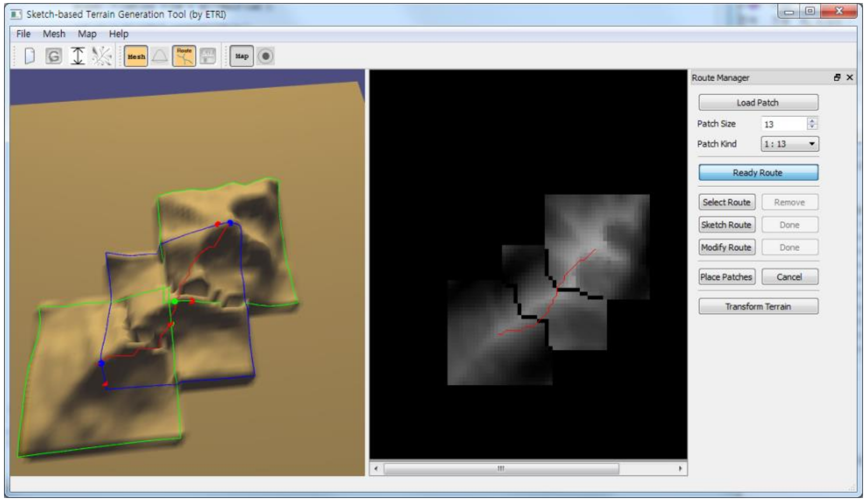


# Terrain Synthesis (5)

## Patch Merging

**Overlapped Region** **Optimal Seam Finding** **Seam Removing**





# Terrain Synthesis (6)

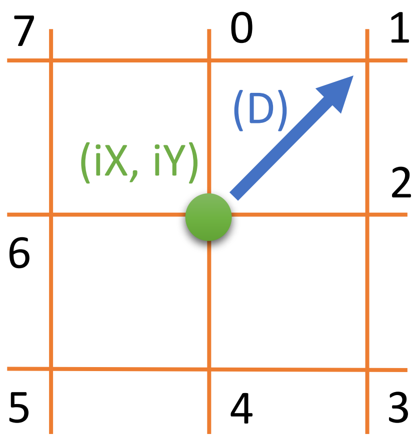
## Result

# Terrain Synthesis (7)

## Data Format: Feature Line

#Header
dHeightMap [sPathFile] [nRows] [nColumns]; the reference Height Map
eType [ridge | valley | all]; a type of feature line
nConnects [n]

#Data
{ [iX] [iY] [iD], … }
; (iX, iY) is the center point
; (iD) is the direction of connection, has the value [0, 7]



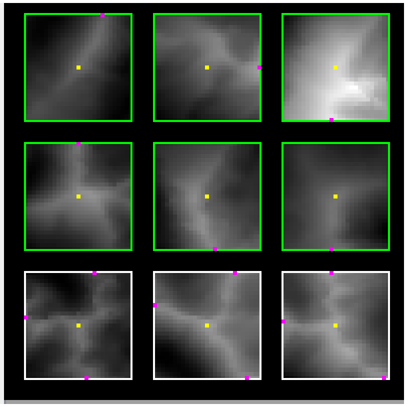
# Terrain Synthesis (8)

## Data Format: Patch Set

#Header
nPatches [n]
nPatchSize [n]

#Patch 0
[nEPs] { [iX] [iY], …}; number of End-Points and list of End-Points
{ [iH], … }; Height Map of the Patch, Size [nPatchSize*2+1]^2

…



# Terrain Synthesis (9)

## Analysis

### Only 2D sketches are allowed

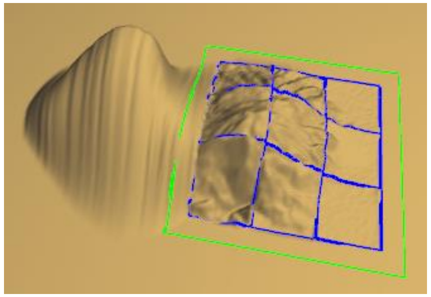
**Can control only a shadow line**

**except Silhouette, Boundaries**

# New methods

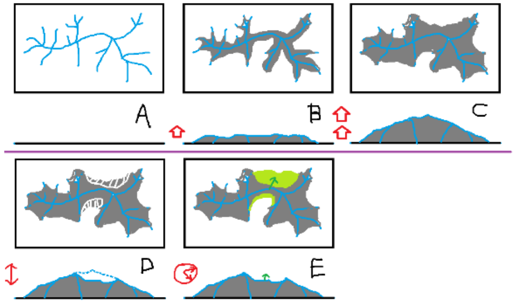
## Landform Composition

### Landform + patch comp.



## Land-Outline Sketching

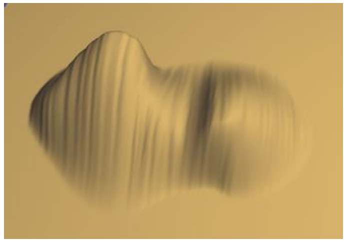
### Chain of Land-Outlines



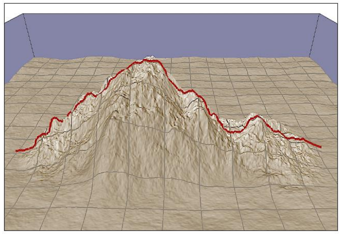
# Landform Composition (1)

## Situation

- Landform has flat surface



- Noise delivers less reality



## Goal

- Terrain has more reality

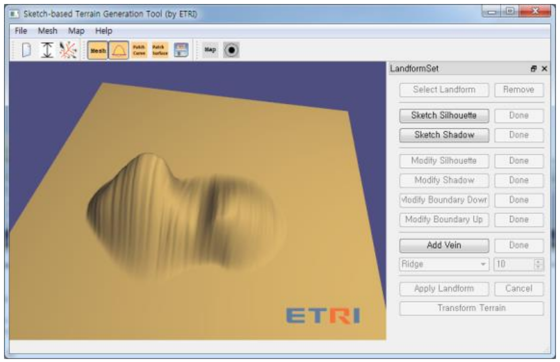
## Idea

- Use DEM patches

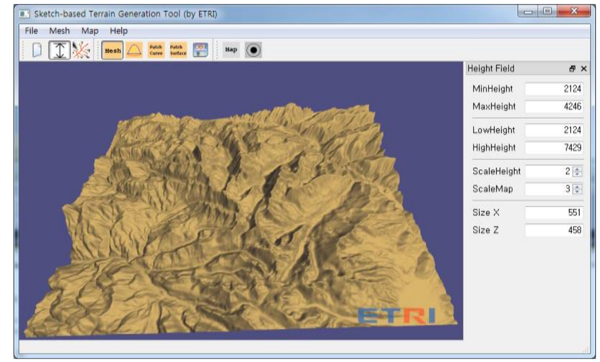
# Landform Composition (2)

## Process

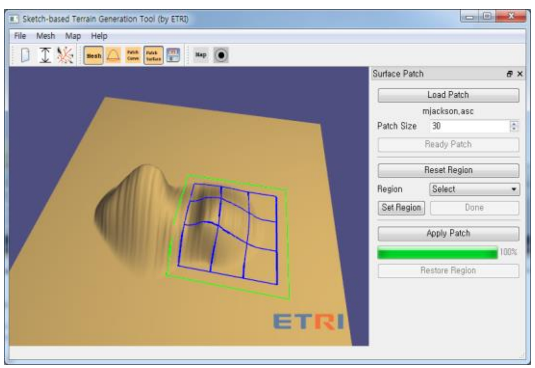
### Landform Generation



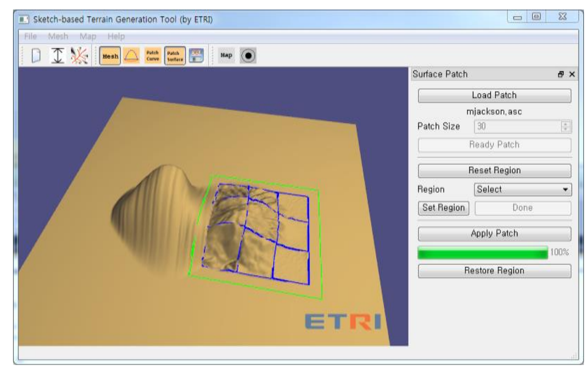
### Load the reference DEM



### Set Region

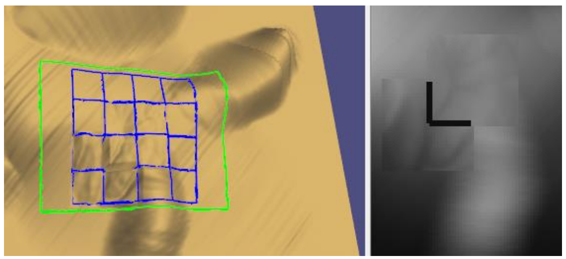


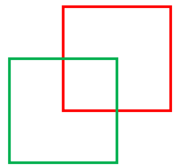
### DEM Patch Composition

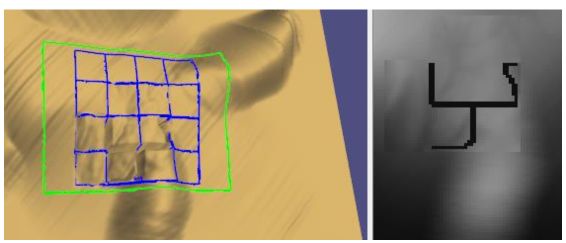


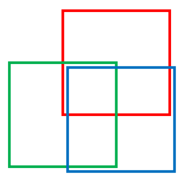
# Landform Composition (4)

## DEM Patch Composition

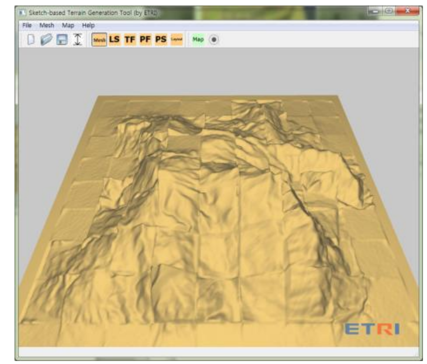




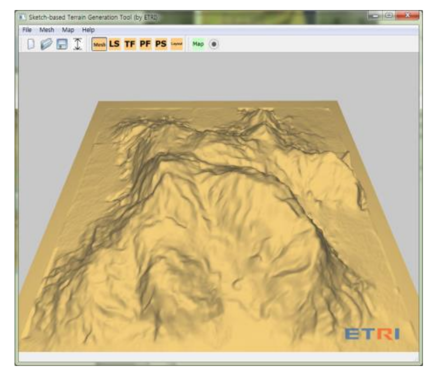




**Without seam removing**



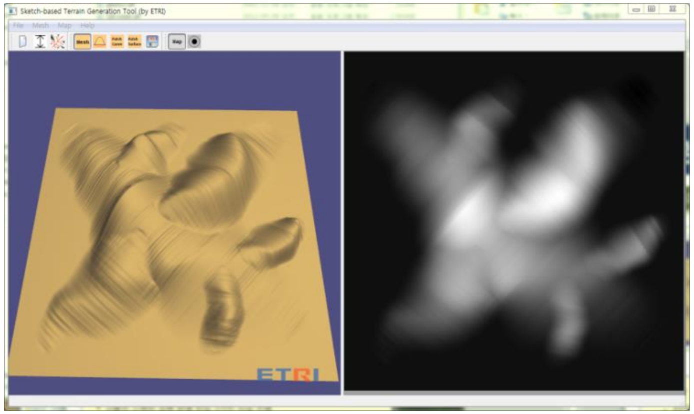
**With seam removing**



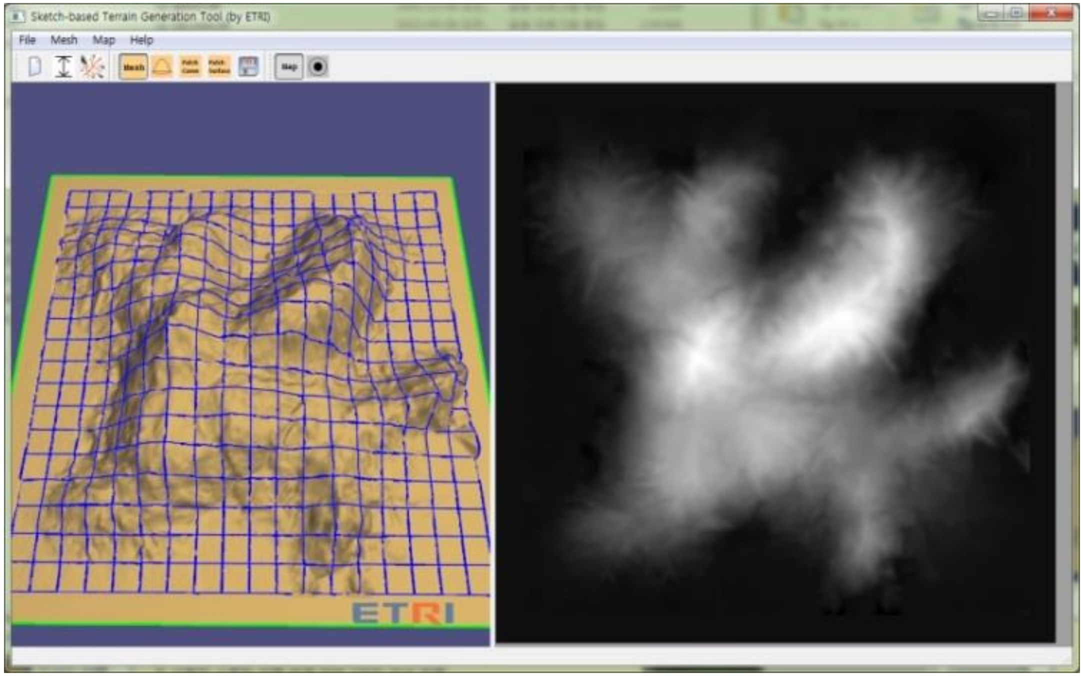
# Landform Composition (5)

## Result

### Landform Generation



### DEM Patch Composition

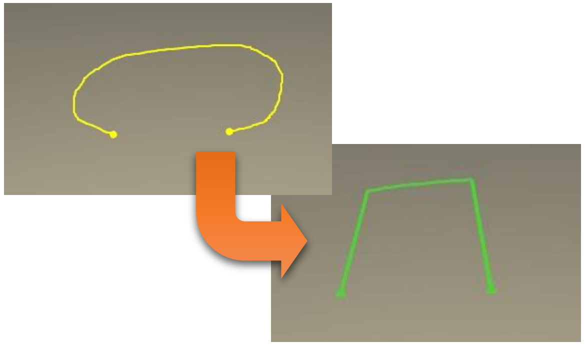


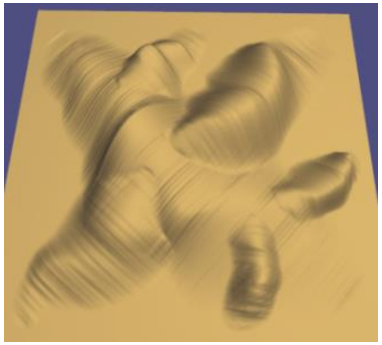

### Load DEM

# Land-Outline Sketching (1)

## Situation

- Landform is too simple to complex terrain





## Goal

- More useful method for complex terrain

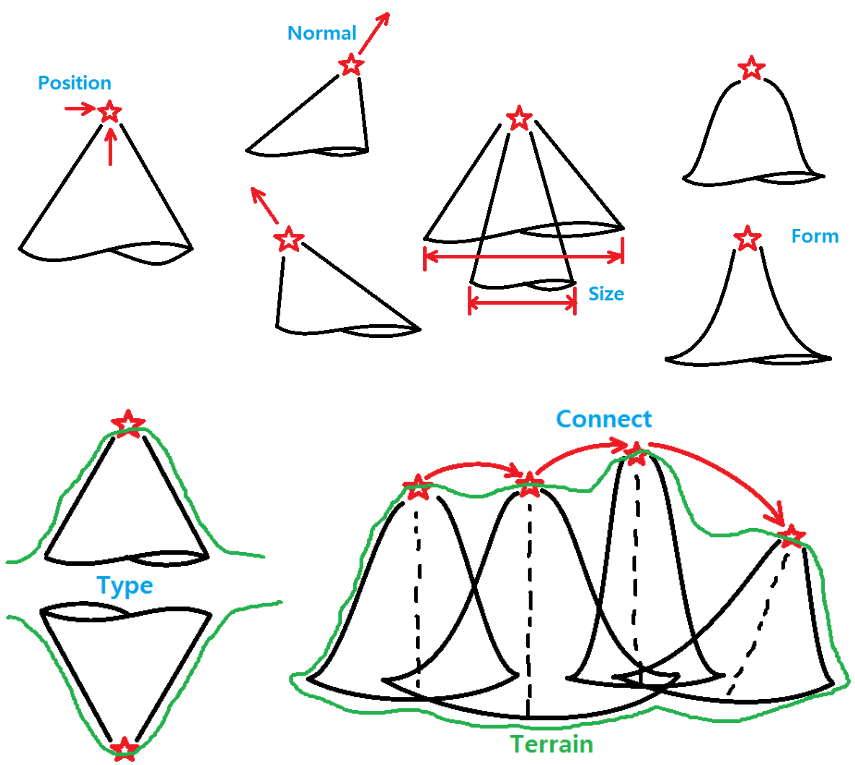
## Idea

- Regard a terrain as a set of primitive shape

# Land-Outline Sketching (2)

## Land-Primitive Structure

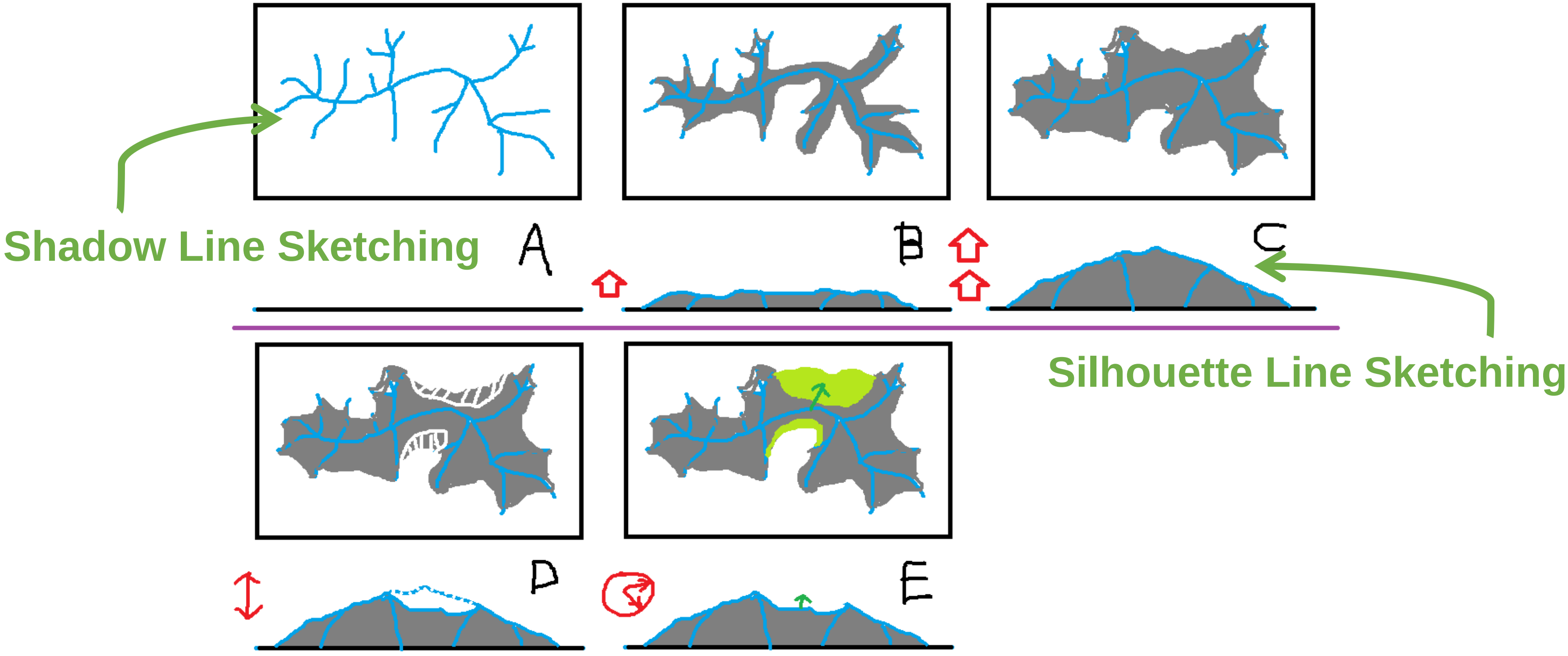
**Land-Primitive is a sort of Landform Unit**



# Land-Outline Sketching (3)

## Land-Outline Sketching Concept

**Land-Outline is converted into the chain of Land-Primitives**

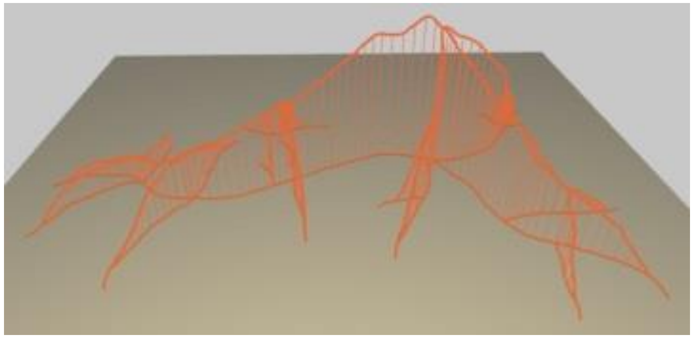


# Land-Outline Sketching (4)

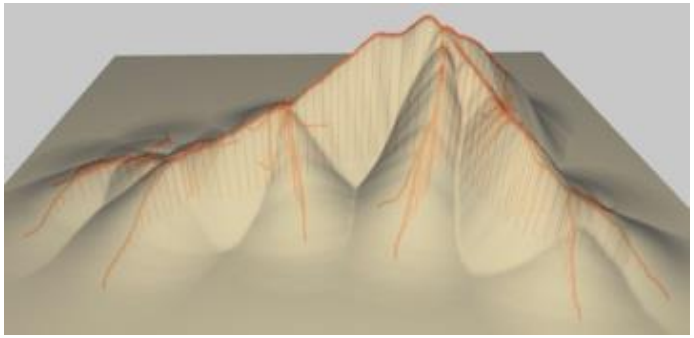
## Process

**Shadow Line Sketching**

**Silhouette Line Sketching**

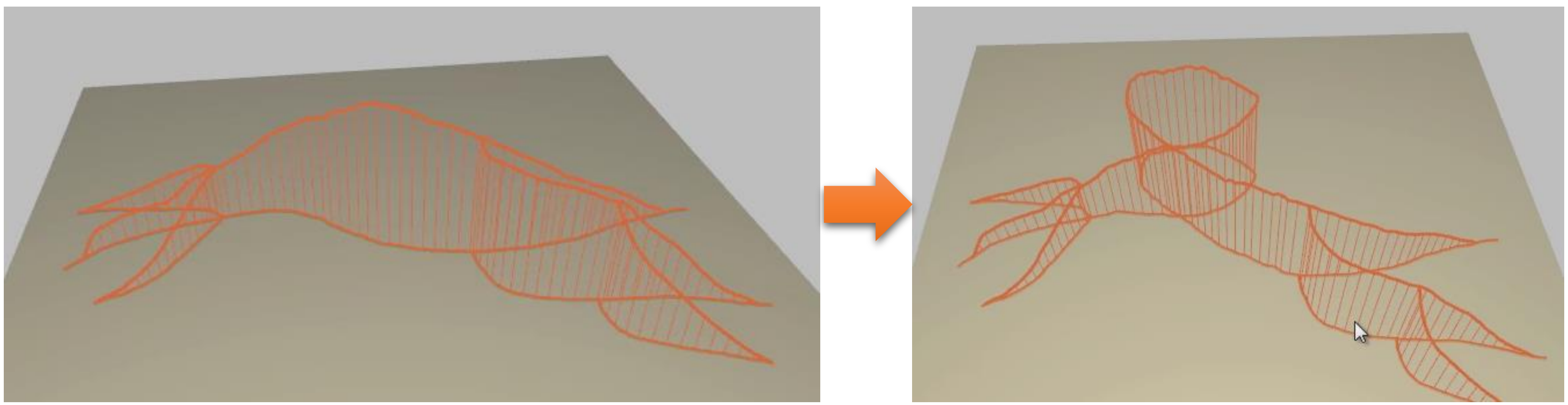


**Convert into Land-Primitives**



# Land-Outline Sketching (5)

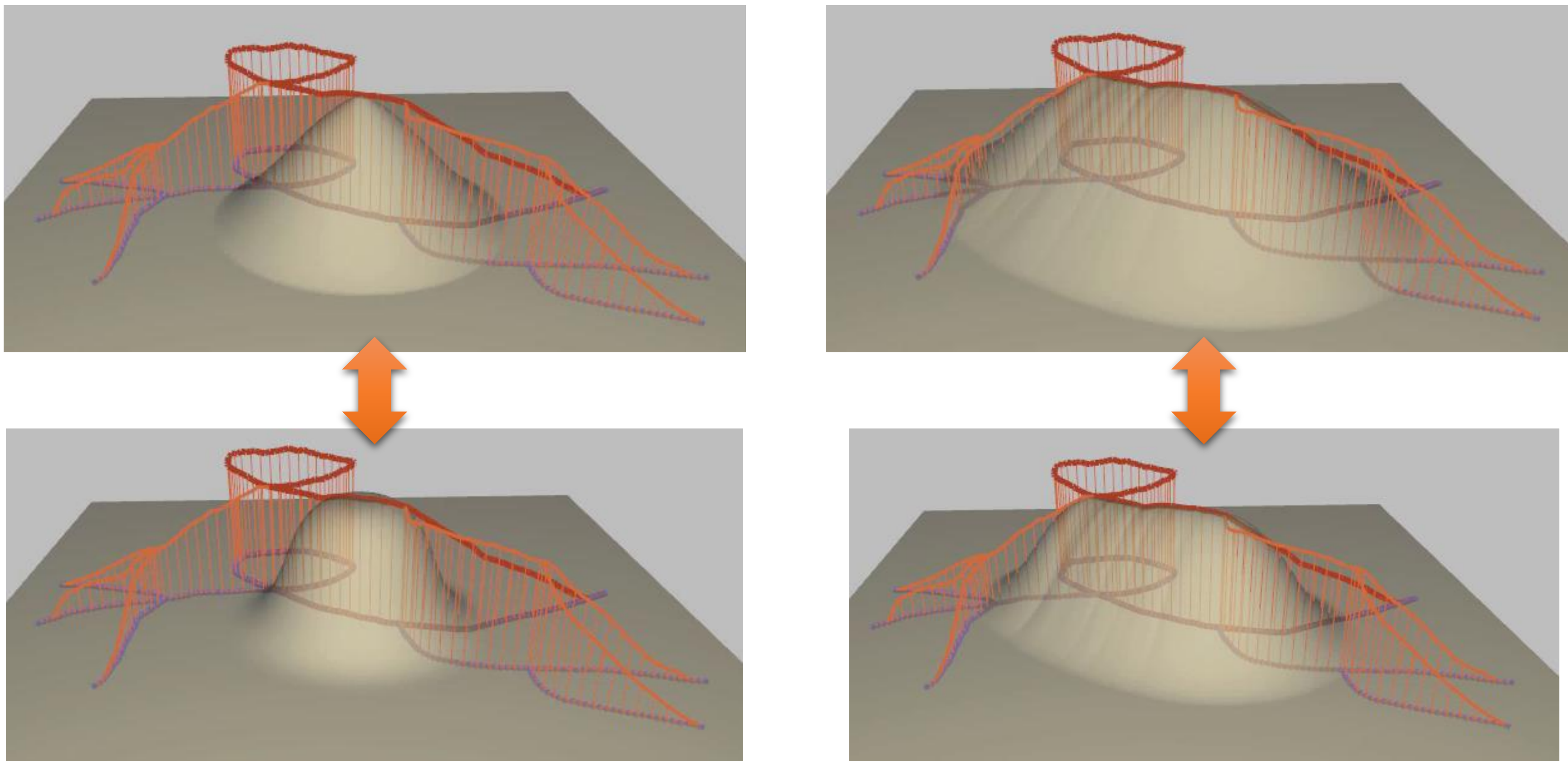
## Shadow Line Editing



# Land-Outline Sketching (6)

## Land-Primitive Editing

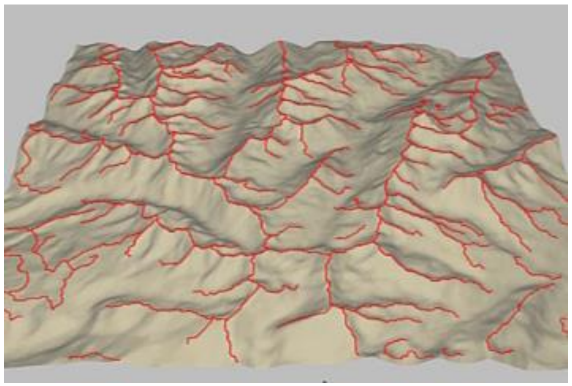
**One-by-One or Series**



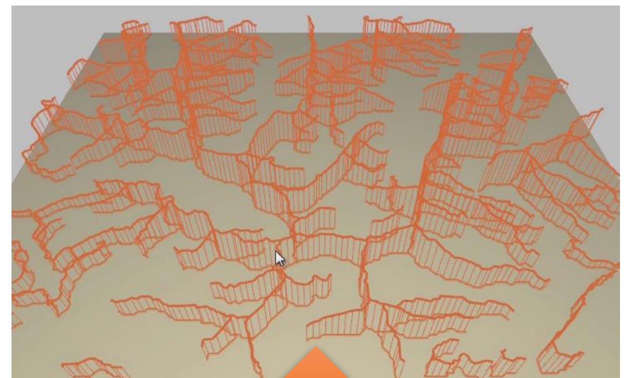
# Land-Outline Sketching (7)

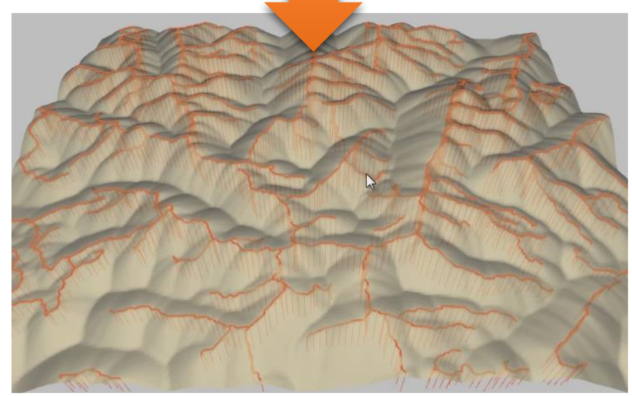
## Convert Features into Primitives

**Load Feature Lines**



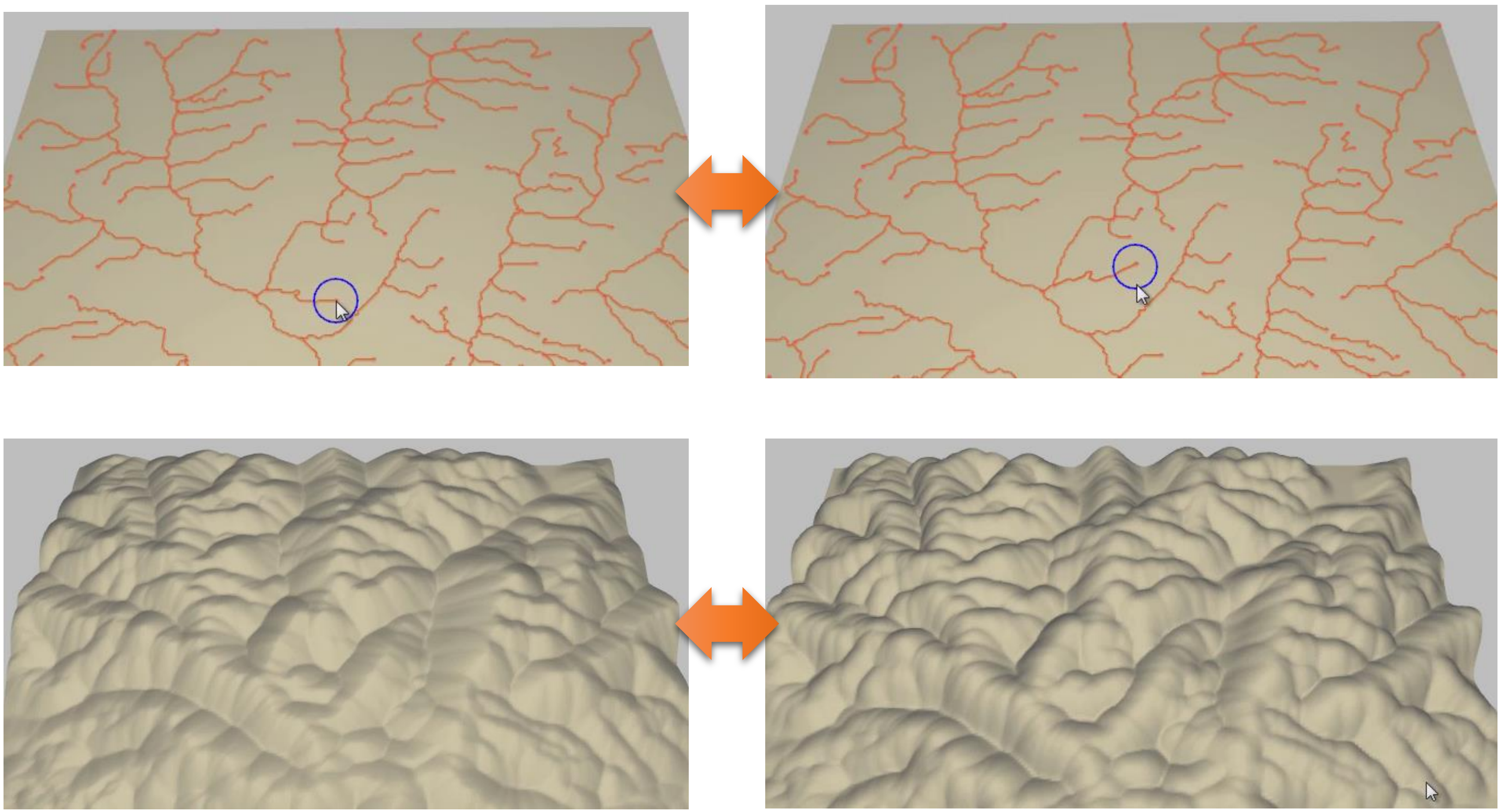
**Conversion**





# Land-Outline Sketching (8)

## Land-Outline and Land-Primitive Editing



# Land-Outline Sketching (9)

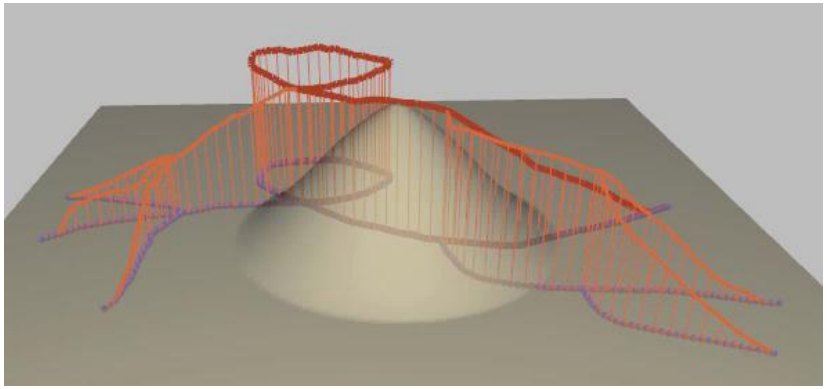
## Data Format

```
#Header
dHeightMap [sPathFile] [nRows] [nColumns]; the reference Height Map
nPrimtives [n]

#Primitive 0
[iX] [iY] [iZ]; position
[iNext]; next pointer to form the chain
[bData]; each bit determine whether next parameter is inherited from the previous
        [eType]; type of feature { Ridge | Valley }
        [fSize]; bottom radius
        [fTheta] [fPhi]; normal vector
        [fGain]; gain value to control the shape of form

…
```

# RBF-based Terrain Modeling (1)

**Someone said to me,**

**"Land-Primitive looks like a RBF"**

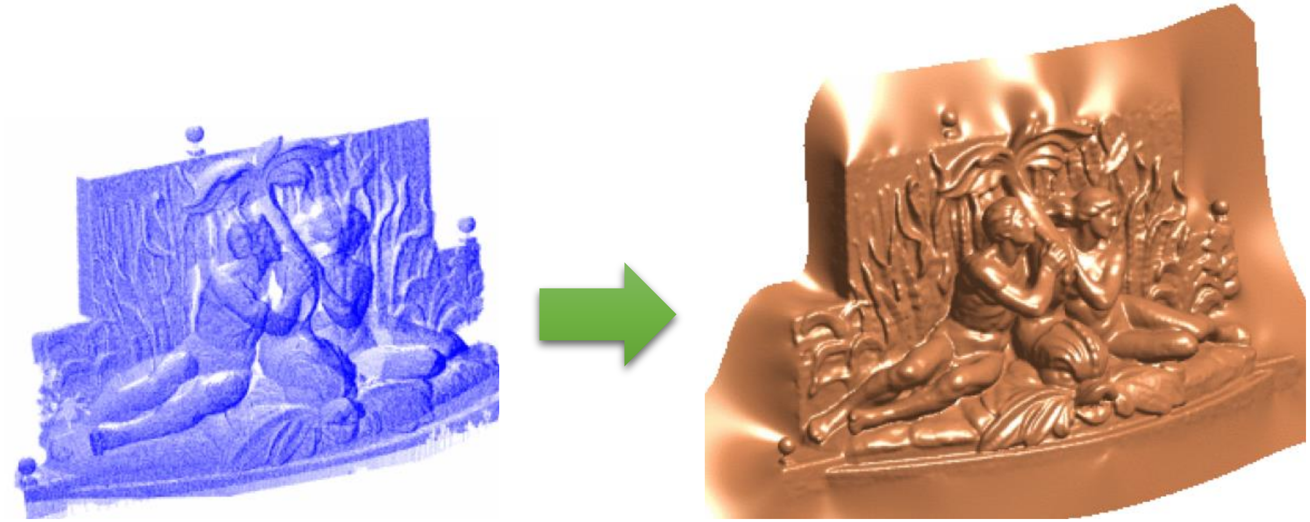


**what is RBF?**

**New research begins**

# RBF-based Terrain Modeling (2)

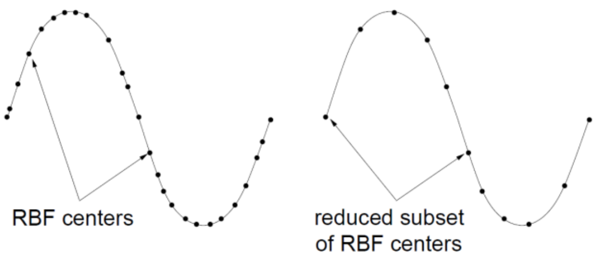
## Reconstruction and Representation of 3D Objects with RBFs (2001)



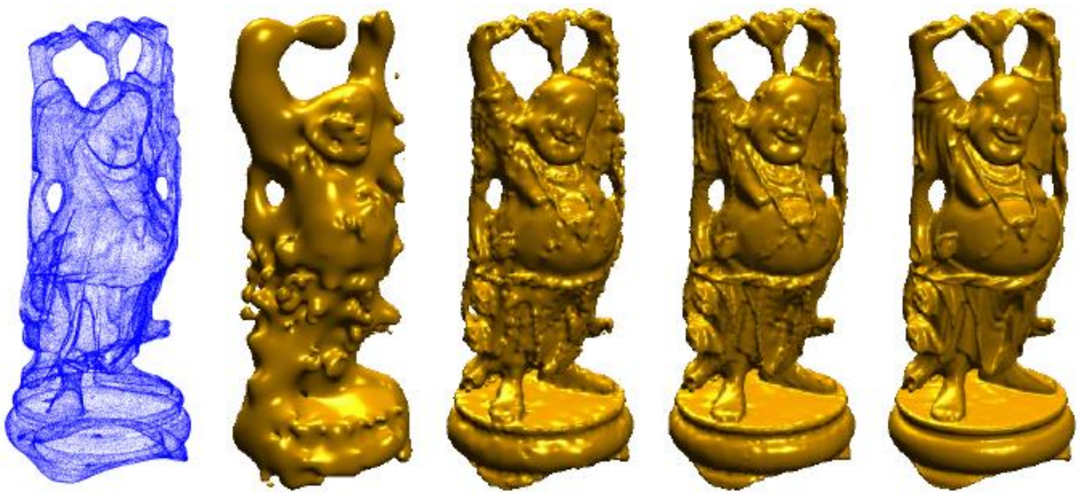
**Using RBF-based Implicit Surfaces convert point cloud into mesh**

# RBF-based Terrain Modeling (3)

## RBF node reduction




1. Choose a subset from the interpolation nodes $x_i$ and fit an RBF only to these.
2. Evaluate the residual, $\varepsilon_i = f_i - s(x_i)$, at all nodes.
3. If $\max\{|\varepsilon_i|\} <$ *fitting accuracy* then stop.
4. Else append new centers where $\varepsilon_i$ is large.
5. Re-fit RBF and goto 2.

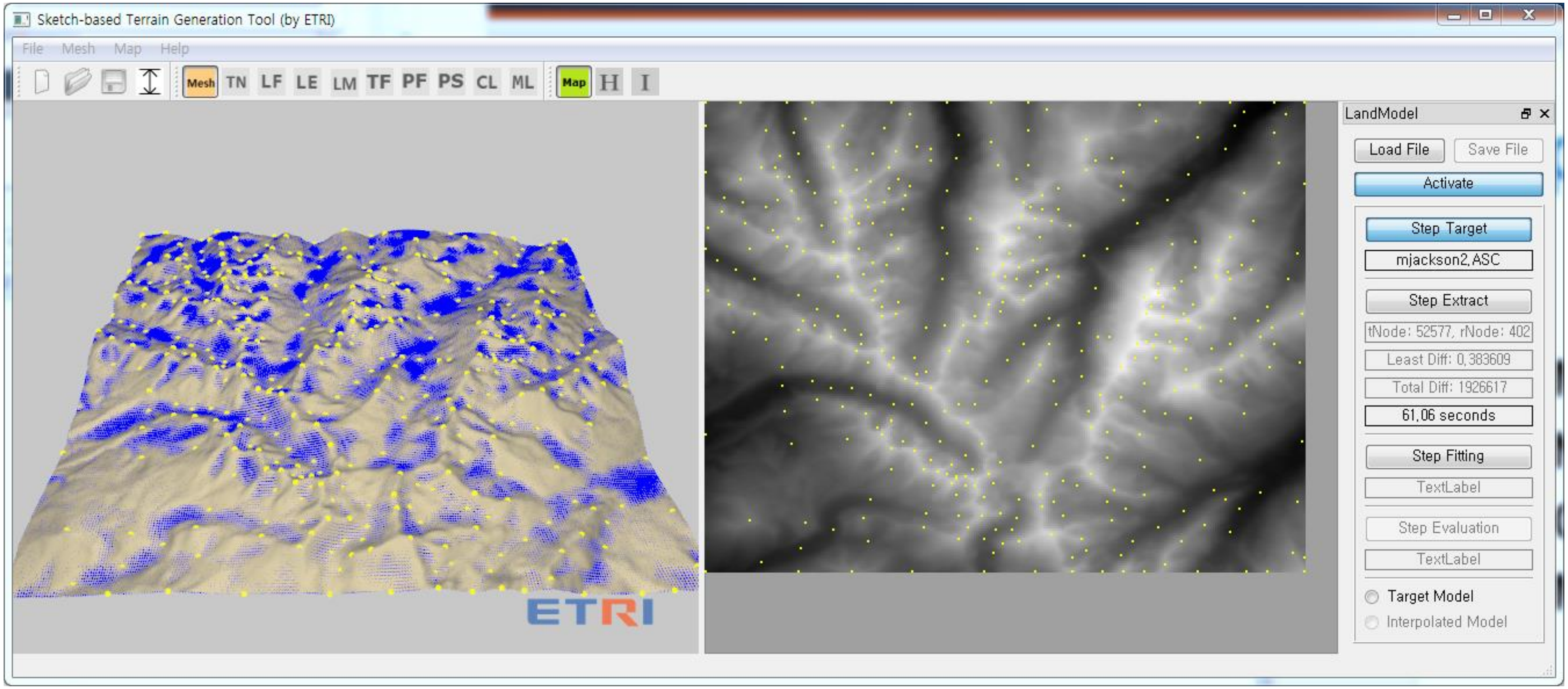


**Original: 544,000 point cloud is**

**Represented by 80,000(14.7%) to a max error 0.0005**

# RBF-based Terrain Modeling (3)

## RBF-based Terrain Modeling



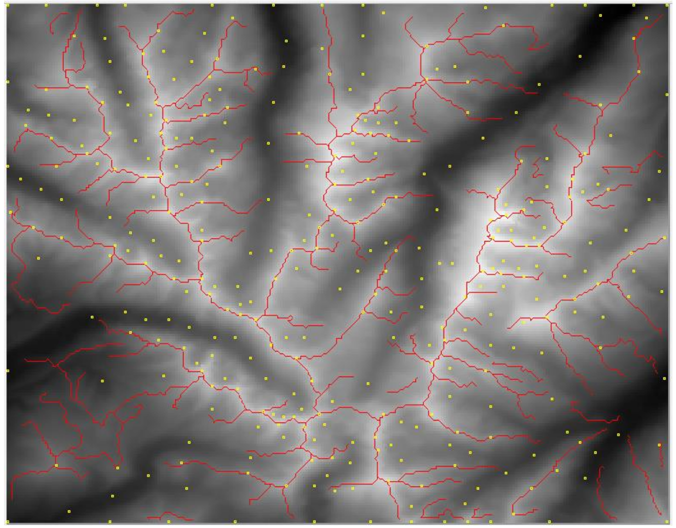

**Map Size: 259 X 203, Nodes: 52577**

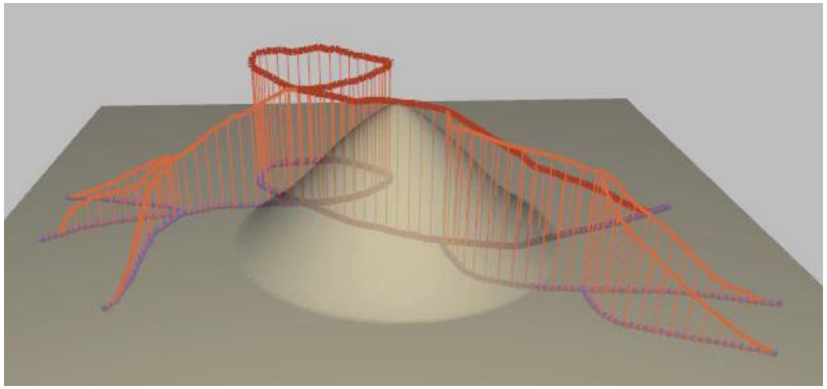
# RBF-based Terrain Modeling (4)

## Highlights

- Terrain Data Compression (under experiments)
  - ➢ The performance is depended on the choice of RBF

- High-weighted RBF nodes are located on feature lines
  - ➢ Land-Outline represents the outline of terrain





# RBF-based Terrain Modeling (4)

## Data Format

```
#Header of ArcInfo ASCII grid format
ncols [n]; x size
nrows [n]; y size
xllcorner [f]; x coordinate of most left grid point
yllcorner [f]; x coordinate of most bottom grid point
cellsize [f]; distance between grid points
NODATA_values [i]; flag value to point out no height
#Extended Header
afImprove [fC1] [fC2] [fC3]; low degree polynomial constants to improve accuracy
nNodes [n]; number of RBF nodes

#Data
{ [iX] [iY] [iH], … }
; ([iX], [iY]) is the coordinate of RBF nodes
; ([iH]) is the real height of RBF node
; Order of RBF nodes is important, high-weighted RBF node is placed in the head
```

# Conclusion

- Proposals
  - 3D landform data format
  - Terrain feature line data format
  - Terrain patch composition data format
  - Land-Primitive data format
  - RBF-based terrain model data format