A 3-D VR MODEL FOR OPTIMAL ALIGNMENT SEARCH SYSTEM OF HIGHWAY DESIGN (OHPASS) USING ASTER GDEM

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Introduction

- How can we design good highway alignments?
  - Reduce construction cost for earthwork, bridges, tunnels etc.
  - Abide by legal standards and constraints
  - Optimize driving safety by minimizing short curves with small radii
- In Japan:
  - Most highways go through mountainous areas
  - A great amount of earthwork, long bridges and tunnels are necessary
  - Road designers have created alignments using CAD software such as AutoCAD which includes real terrain data

Designers require automatic optimization or support systems for designing highway alignments.

Objectives

- Automatic search for optimal 3-D alignments

(horizontal and vertical performed simultaneously)

- Realistic alignment results

(including clothoid curves)

- Abides by constraints

(Japanese highway design standards)

- Considers realistic earthwork costs (with digital terrain model) and realistic construction costs for bridges and tunnels
- Avoids inaccessible zones

- Efficient solution algorithm finds global optimum

(by reducing parameters and using Genetic Algorithms)

Horizontal and Vertical Alignment

- Horizontal alignments between two passing points are classified into three types to maximize the radius of curvature
- A curve is replaced with clothoid + circular arc + clothoid to keep with highway design standards
- Vertical alignments are also determined and classified into three types

*For more details, please refer to the proceedings or ask me later.

Evaluation Functions (1)

- Construction cost
  - Earthwork cost
    - Amount of cut and fill is calculated from detailed digital terrain data (2m x 2m mesh)
    - Earthwork balance is also considered
  - Bridges and tunnels
    - Bridge cost is determined by length and height
    - Tunnel cost depends on its length
    - Unit cost is derived from actual Japanese highway examples

Evaluation Functions (2)

- Constraints and preferable conditions
  - Defined by laws and design standards
- Control points (inaccessible zones)
  - Horizontal zones (should be avoided, e.g. school or factory)
  - Vertical zones (should have a lower elevation than the alignment, e.g. river or road)
  - Penalties are determined

Horizontal Alignments

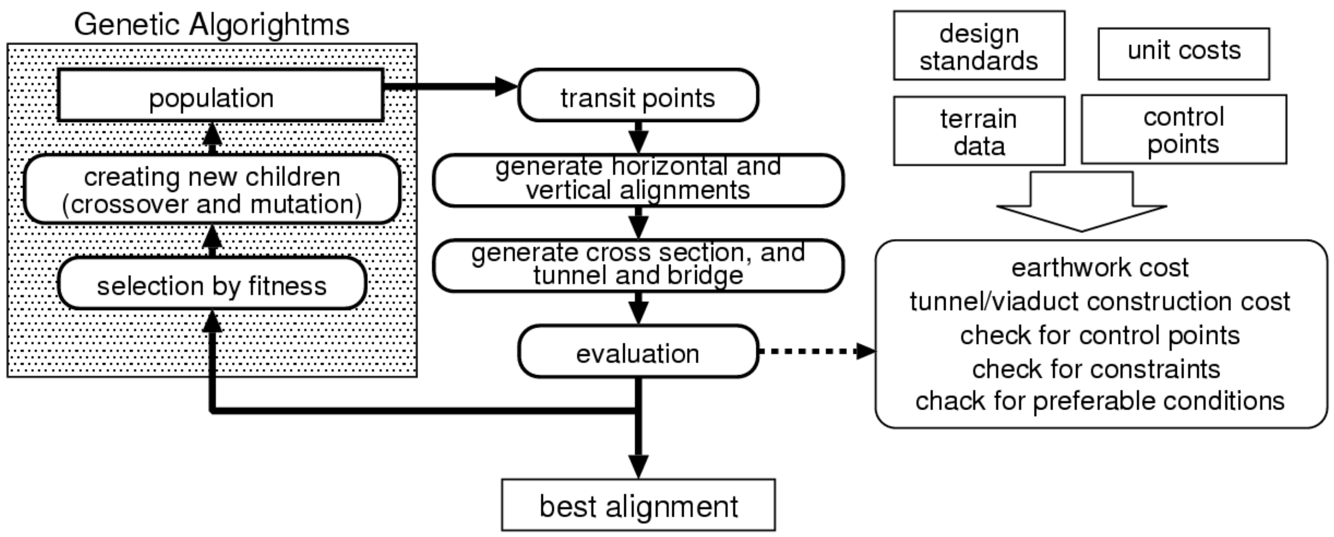
parameter	condition	note
length of straight line L[m]	$160 \leq L \leq 1600$	between reverse directional curve
	$500 \leq L \leq 1600$	between same directional curve
length of circular curve L[m]	$500 \leq L$	
radius of circular curve R [m]	$600 \leq R \leq 10000$	
radius of S-shaped curve R_1, R_2[m]	$1/3 \leq R_1/R_2 \leq 3$	
radius of egg-shaped curve R_1, R_2[m]	$1/1.5 \leq R_1/R_2 \leq 1.5$	
adjoining clothoid curve A_1, A_2[m]	$1/2 \leq A_1/A_2 \leq 2$	

Vertical Alignments

length of parabolic L[m]	$500 \leq L$	
radius of convex curve R [m]	$4500 \leq R$	
radius of concave curve R [m]	$3000 \leq R$	
grade θ [%]	$\theta \leq 4.0$	everywhere
	$0.3 \leq \theta$	at straight line
	$0.3 \leq \theta$	at tunnel

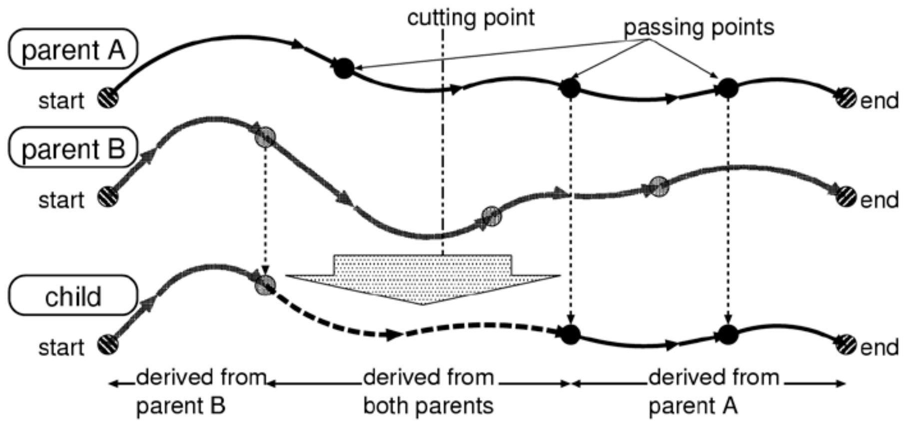
Genetic Algorithm (GA) Optimization

- Each *Individual* is a real number array representation of passing points
- *A Population* usually includes hundreds *individuals*
- Evaluation scores are calculated and include earthwork cost, construction cost for structures, penalties for alignment constraints, preferable conditions, and inaccessible areas

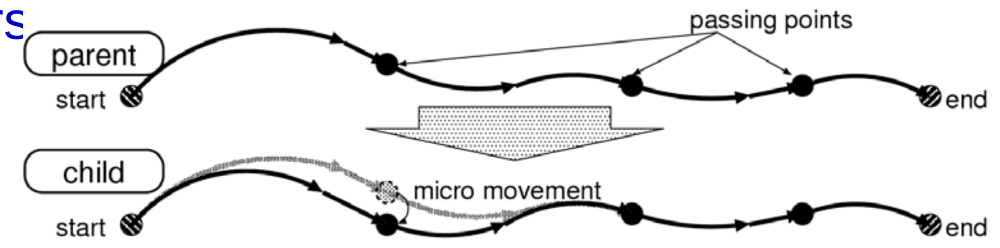


Genetic Operations

- **One-point crossover:**
  Parent individuals are divided into two parts at the same cutting point, and child individuals are created.

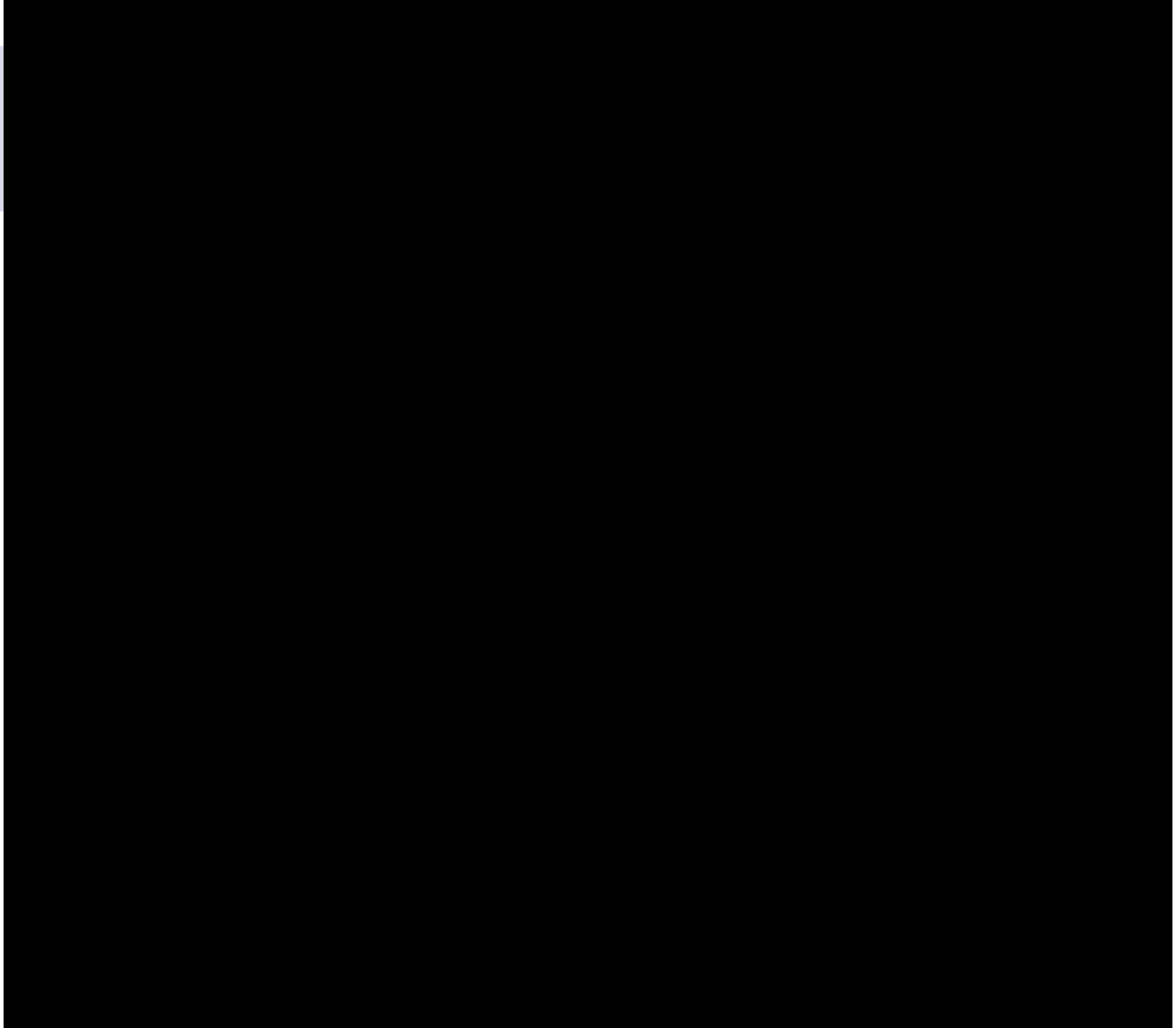


- **Mutation:**
  Changes in 1 or 2 parameters of randomly selected passing points



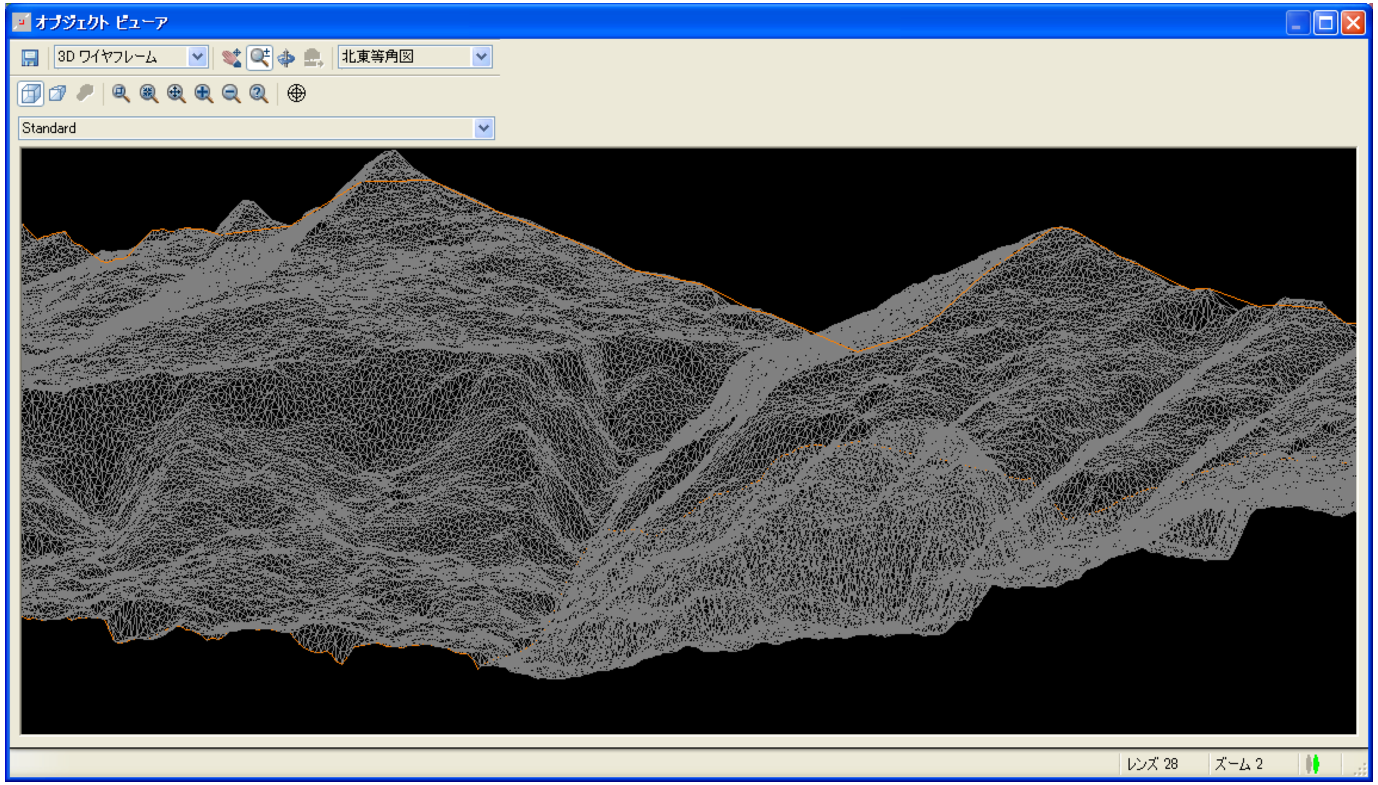
Conclusion

- Achievement
  - Search for optimal highway 3-D alignments by Genetic Algorithms
  - Realistic alignments, constraints, and cost functions
  - Development of the `OHPASS' system and evaluation with a real highway example
  - Significant improvement when compared to past designs
- Future work
  - Evaluate system with various other highways
  - Increase speed in PC cluster or improve algorithm
  - Consider other evaluation functions (e.g.. right-of-way cost or environmental cost)



Digital TeRRAIN DATA IN OHPASS （ASTER GDEM）

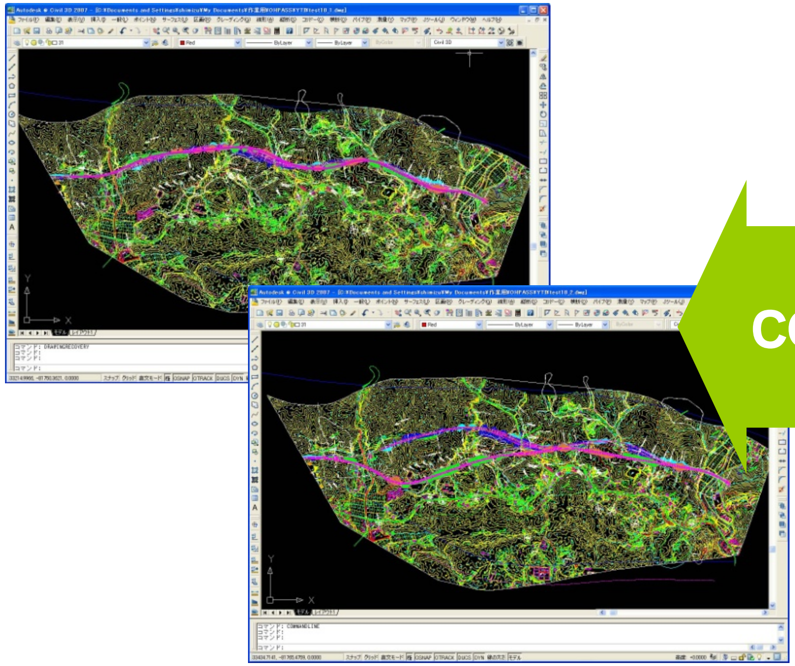
Data that covers all the topographic data in the world.



Data Exchange with VR

Data links with the plug-in by UC-win/Road for Civil 3D

[OHPASS]



COM API

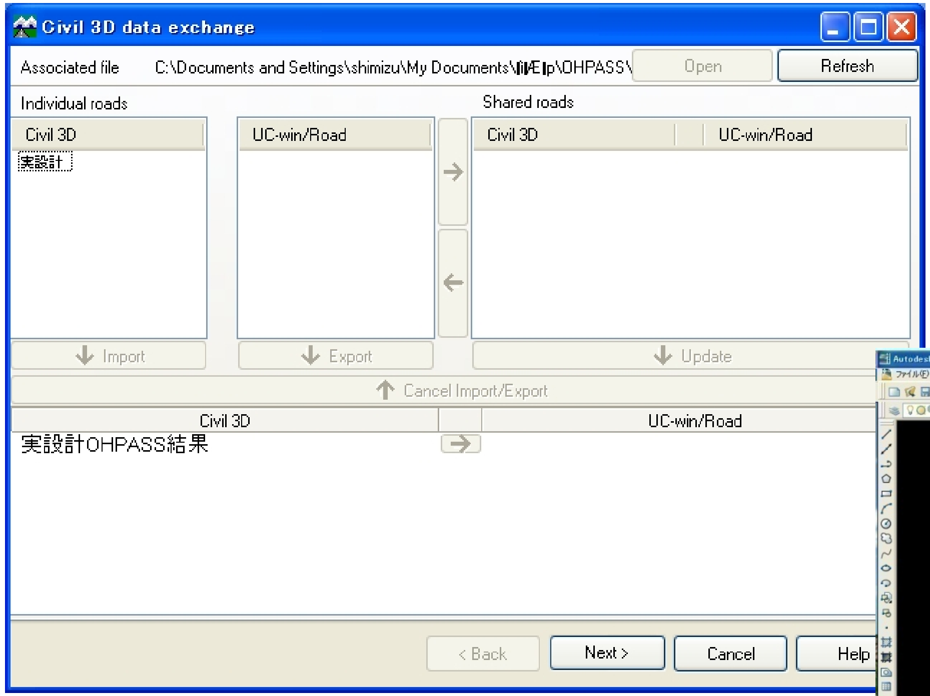
[UC-win/Road]

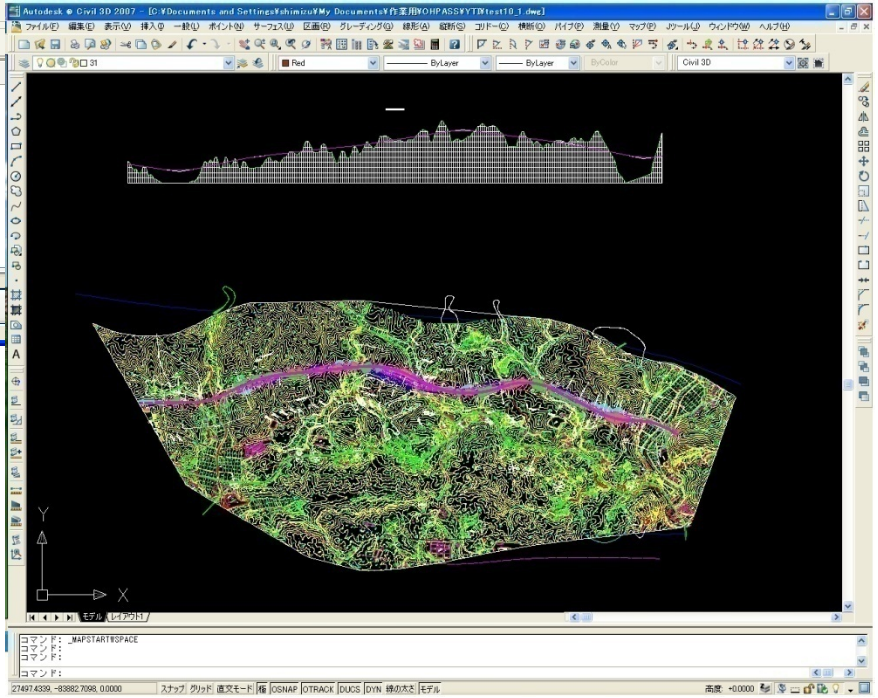
[OHPASS] data exchange by COM API

Data Exchange with VR

Data exchange procedure

STEP 1: Selection of the target road



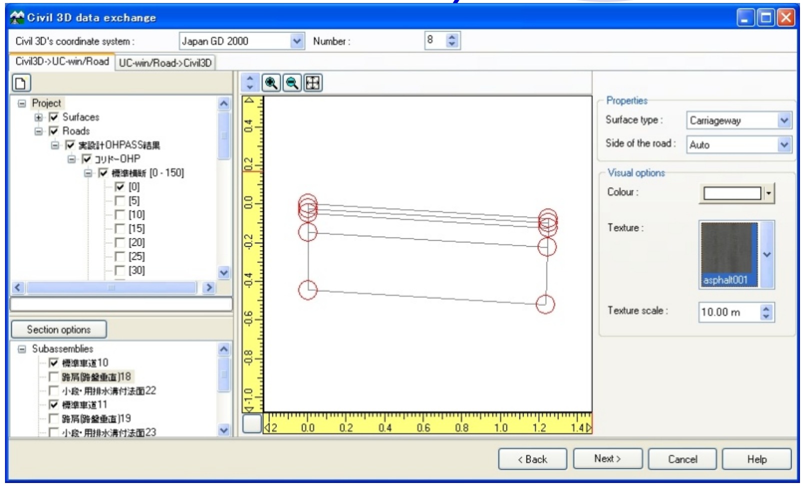


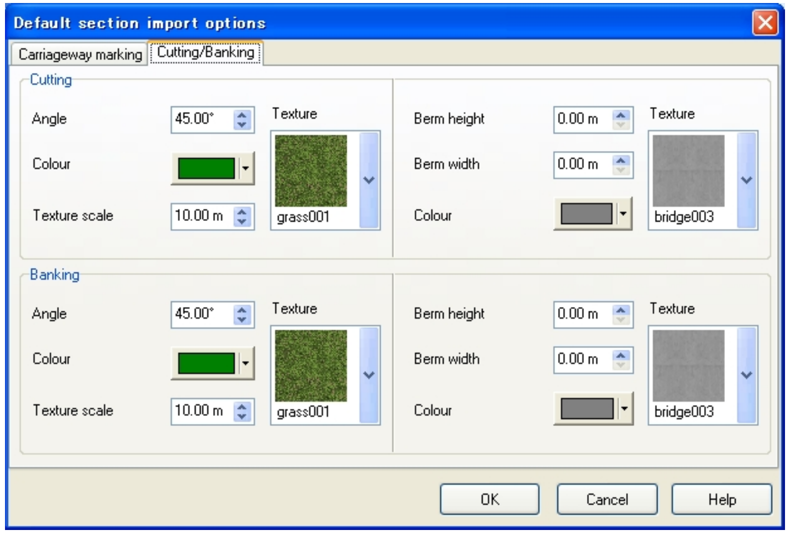
*Target road list
 -Road list in OHPASS
 -Road list in UC-win/Road
*Share transferred road data

Data Exchange with VR

STEP 2: Cross section setup (OHPASS→UC-win/Road)

*Selection of sub-assembly and editing
  -Road surface type setup
  -Texture setup
*Setup of slope / step inclines
  -Angle
  -Texture setup





Thank you

Please contact us with questions

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