2020 International Smart Cities e-Forum

智慧城市國際線上論壇

Virtual Cities:

Planning & Design using VR & Genetic Algorithm

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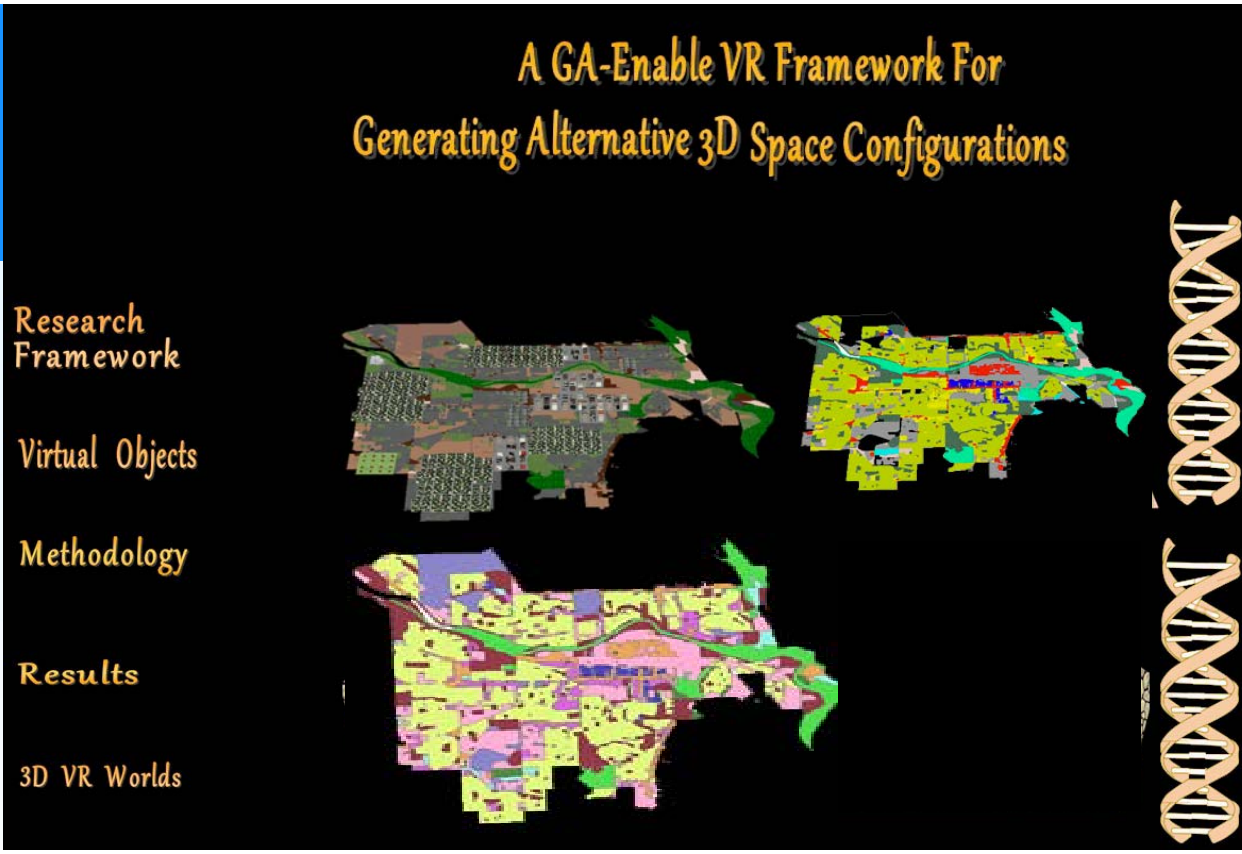


Background

- Planning and managing cities – increasingly complex, as the population of cities increases geometrically
- To meet the demands of the increasing population, the limited resources are subject to over exploitation
- To attain long-term sustainable development proper planning is needed
- Landuse planning involves multiple stakeholders, multiple demands or objectives must be satisfied

Virtual Planning

- 3D models provides a key component – "sense of immersion"
- 3D models better enables understanding in inherent characteristics and processes
- Visualization provides an ability to better understand and interact with data

Virtual Planning

- To explore the use of visualization tools for planning and designing urban spaces
- Customize the plan of a site to the client's requirements for how they want to use the space right in front of their eyes
- Full picture – we want the planners to be able to see (near) final proposed designs

Optimization & VR

- In the following demonstration example, first Genetic Algorithm based optimization was performed and selected Pareto plans were visualized using Virtual Reality

- To design a GA-based Multiobjective Optimization procedure that can generate a set of Pareto-optimal plans for maximizing three objectives namely green space, space for public service, and housing capacity.

Genetic Algorithms (GA)

- ➢ Core of GA – Selection and Variation
- ➢ Wide-ranging search procedures
- ➢ Overcome limitations of methods
  - \- Can handle multiobjective problems
  - \- Can handle very large search spaces

```
p(t)                                  ; Initiate the population
EVAL p(t)                             ; Evaluate the population
                                        Calculate fitness using
                                        objective functions
while (!= termination -clause)do      ; check for satisfaction of criteria
                                        Maximum number of
                                        iterations reached?
t := t+1                              ; proceed to subsequent generation
Create p(t) from p(t-1)               ; Generate pop using genetic operators
Evaluate p(t)                         ; Again, evaluate the new population
loop
```

GA-Based Multiobjective Optimization

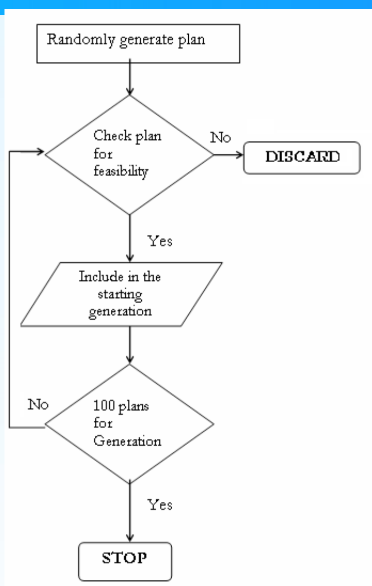
Landuse Type	LU_Code	Integer corresponding To LU_Code
Agricultural Zone	AGRI	0
Commercial Zone	COMM	1
Direct Control	DC	2
Industrial zone	IND	3
Greenspace zone	GS	4
Pubic service zone	PS	5
Residential – High Density	RESH	6
Residential – Low Density	RESL	7
Residential – Medium Density	RESM	8
Urban Reserve	UR	9

- 3 GA objectives (all directly conflicting objectives)
  - o Maximization of per capita green space (PCGS), per capita space for public service (PCPS), and housing density (NumHU)
- Computation of objective values
  - o PCGS and PCPS - Area / Number of residents
  - o NumHU = AreaResL * 50 + AreaResM * 100 + AreaResH * 185
- AreaResL, AreaResM, AreaResH: low, Med, High-density residential area
- GA constraints: Direct control zones & Urban reserves unchanged

A hypothetical representation of a chromosome with integer representation

GA: Starting generation and feasible set

- Sample Study area divided into 135 zones
- Population of initial generation – 100**
  - o Random generation
    100 * 135 integer values – Range 0-9
  - o Plans checked for feasibility
- More than 1 million plans (1,213,400) generated to get 100 feasible plans



Generation of 100 feasible plans for starting generation

GA: Fitness

- Every plan compared with other plans in the same generation
- Values returned by objective functions for $Plan_i$ - $PCGS_i$, $PGPS_i$, $NumHU_i$
- Considering two plans i and j, $Plan_i$ is dominated by $Plan_j$, if
  $PCGS_j > PCGS_i$, $PGPS_j > PGPS_i$, $NumHU_j > NumHU_i$
- If min diff. b/w j & i > zero, then plan j dominates plan I
  $\min(PCGS_j - PCGS_i, PGPS_j - PGPS_i, NumHU_j - NumHU_i) > 0$

$$f_i = \left[1 - \max_{j \neq i}\left(\min\left(\frac{PCGS_j - PCGS_i}{PCGS_{max} - PCGS_{min}}, \frac{PCPS_j - PCPS_i}{PCPS_{max} - PCPS_{min}}, \frac{NumHU_j - NumHU_i}{NumHU_{max} - NumHU_{min}}\right)\right)\right]^p$$

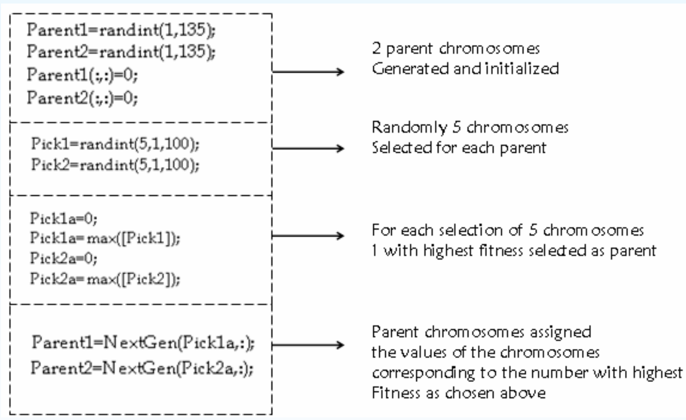
- Every plan must be compared with all other plans in generation

  $\max(\min(PCGS_j - PCGS_i, PGPS_j - PGPS_i, NumHU_j - NumHU_i)) > 0$

  If > 0, then no other plan outperforms plan i in all objectives
  $j \neq i$

GA: Creating Next Generation

- Natural selection
  - $Num_{ret} = Num_{ChrPop} * SelRate$
  - SelRate - Too small - Available genes limited
    - Too large – Bad traits continue to be inherited
  - Previous generation sorted and 20 plans selected (20% SelRate)

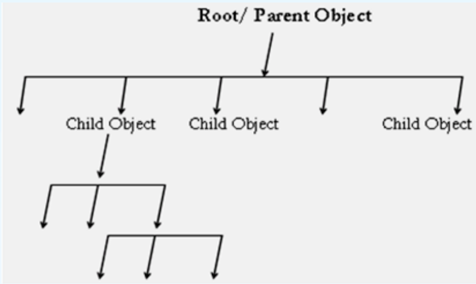


- Selection for mating
  - 2 parents chosen for reproduction (mating)
  - Random Pairing

VR-Based Visualization

➢Visualization used to compare the Pareto plans

➢ Virtual Reality
- o Subset of high fitness Pareto plans selected
- o 3D worlds for selected Pareto plans generated
- o Plans compared to select most suitable plan for current problem



Hierarchical structure for scene definition

➢ Hierarchical structure of scene definition
- o Scene divided into components or objects
- o Objects grouped to form bigger objects

software

- Virtual scenarios - x3D/VRML
- Unity platform
- Java 3D
- Scripting
- Game engine capable of rendering through either through OpenGL or DirectX

HARDWARE

- Desktop/Laptop
  - HP Z800 machine – HP graphics workstation
  - Alien ware Series or Oculus compatible laptops
- Samsung C7000 46inch 3D TV
  - proprietary glasses for binocular vision
- Razer Hydra
  - Built for gams. Recent surge in use for DIY-VR
- Microsoft Kinect
  - Gaming interface MS Xbox; but, this study uses as tracking interface

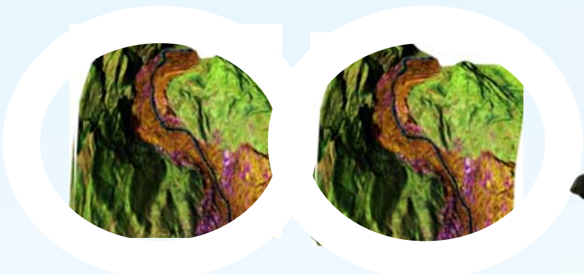
Hydra -Real-time Interaction

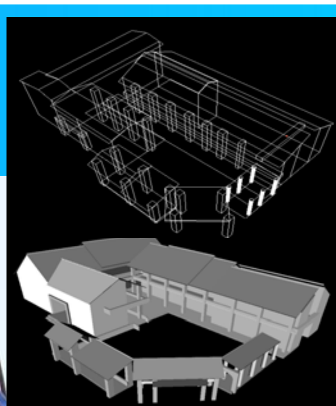
Oculus (VR Display)

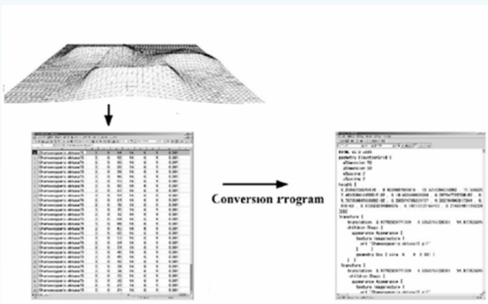
Interface (MS Kinect)

HTC Vive

OCULUS & HTC VIVE







Results and Discussion

➢ Experiments confirm that values suggested by pioneers are correct

- o Medium tournament size
- o Low mutation probability

➢ GA executed for the given landuse region with following parameters

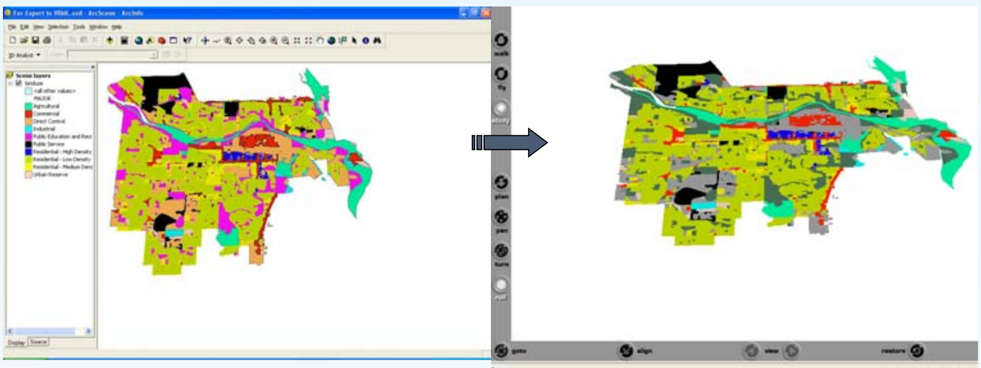
- o Tournament size of 5
- o Mutation probability – 0.05

o GA executed for 100 generations maximizing three objectives

Tournament size	Mutation Probability	Generation size	Ratio of Pareto plans Starting :Final
Low	Low 0.05	100	1:3
	Medium 0.1	100	1:2.5
	High 0.2	100	1:2
Medium	Low 0.05	100	1:4.2
	Medium 0.1	100	1:3
	High 0.2	100	1:3
High	Low 0.05	100	1:3
	Medium 0.1	100	1:3.25
	High 0.2	100	1:3

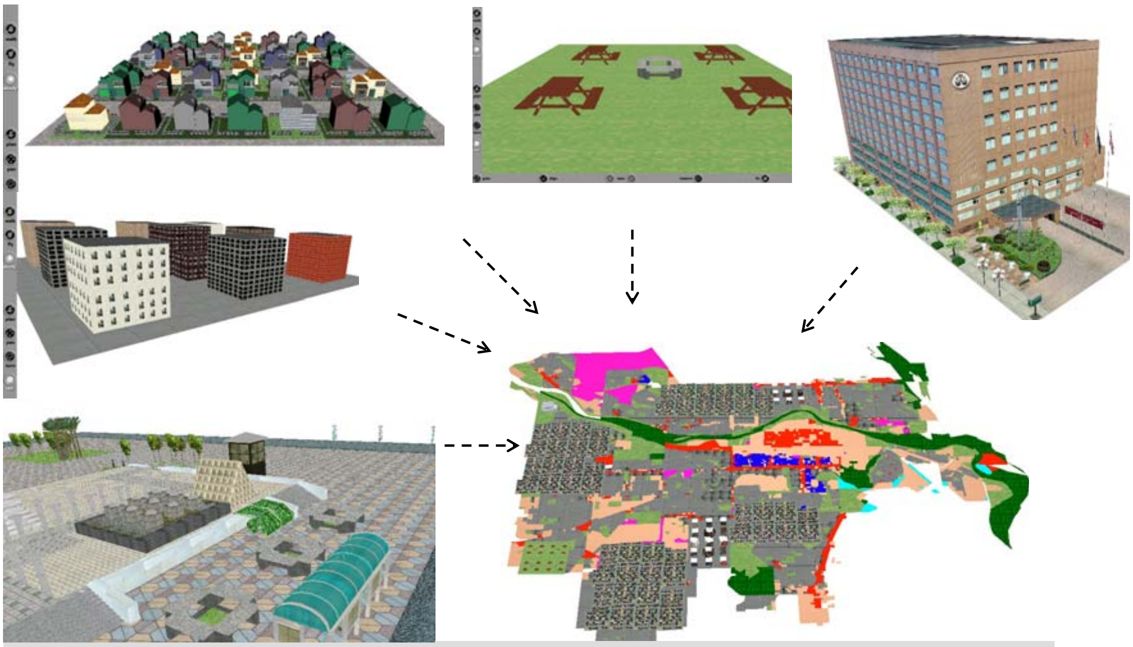
Results and Discussion

Visualizations shown for 2 Pareto Plans



File imported from ArcScene

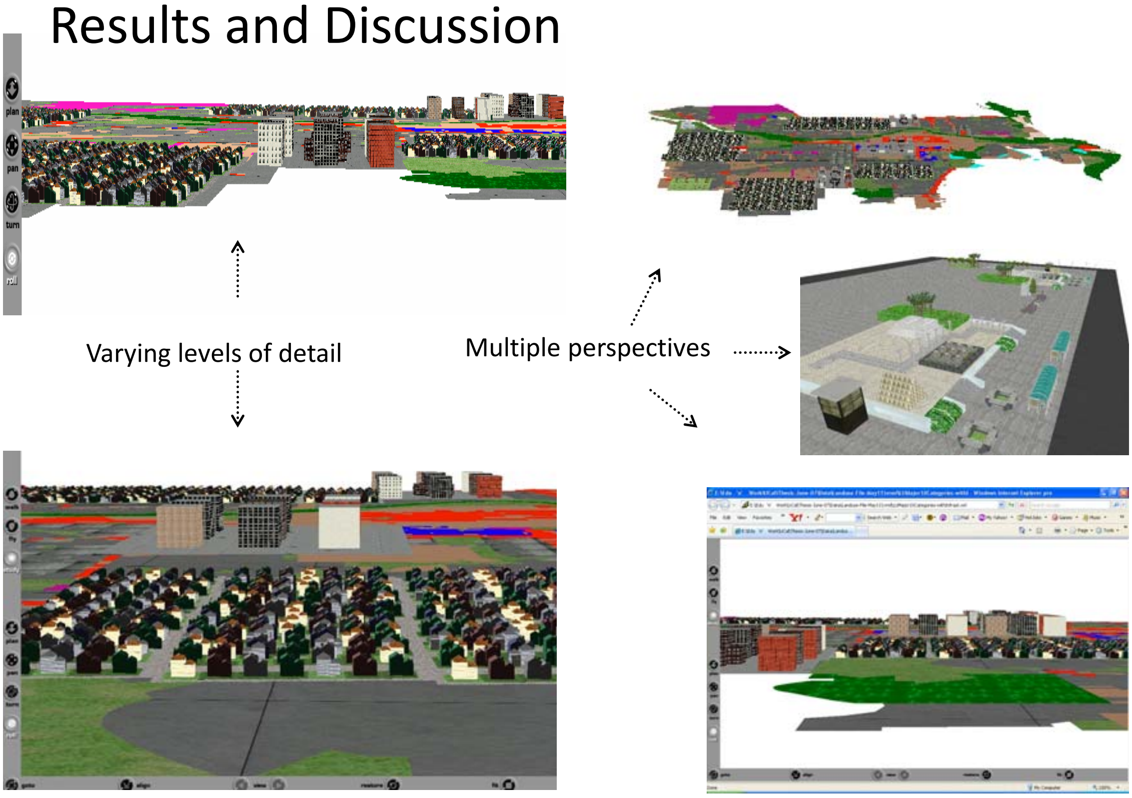
Results and Discussion

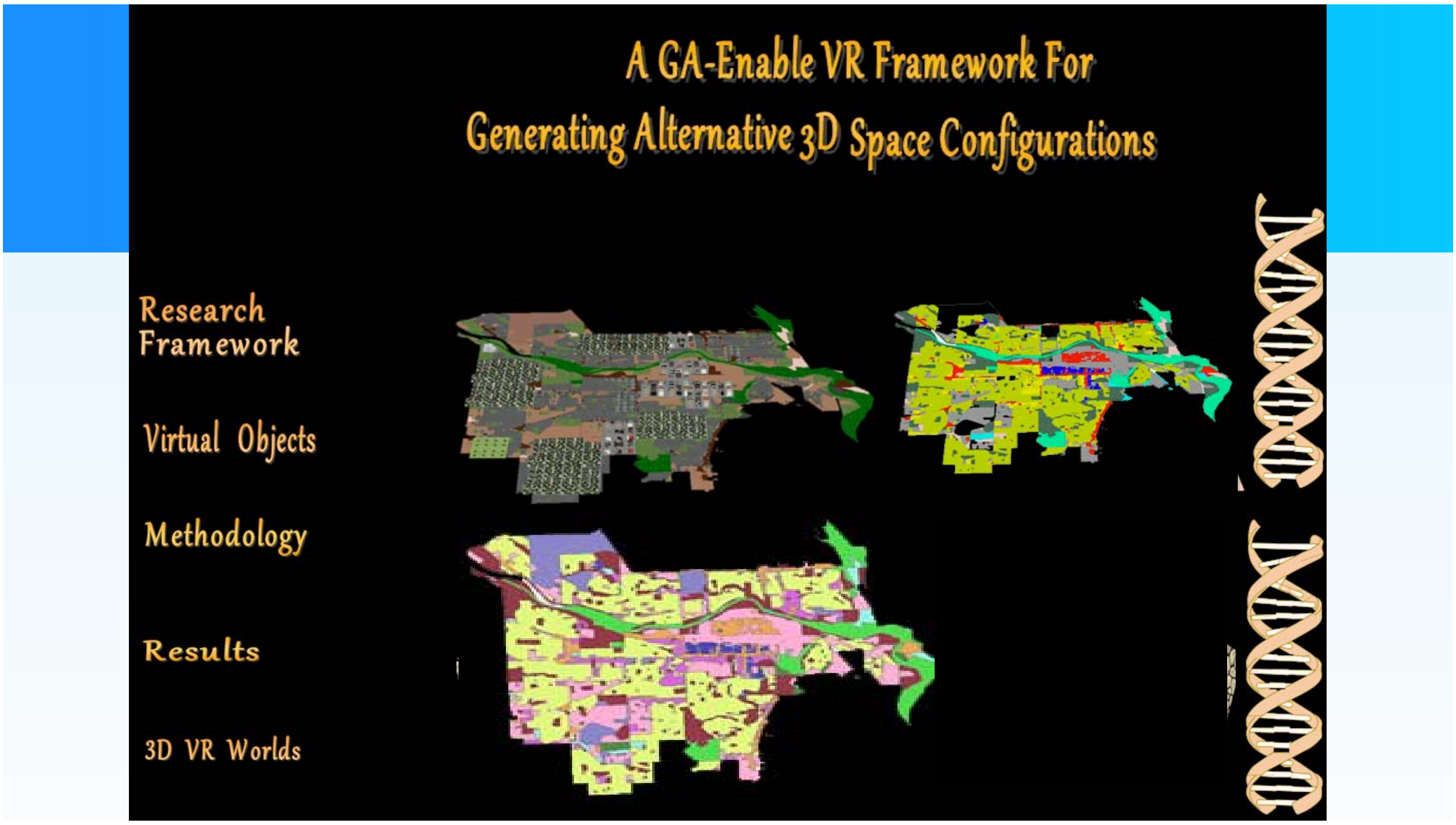


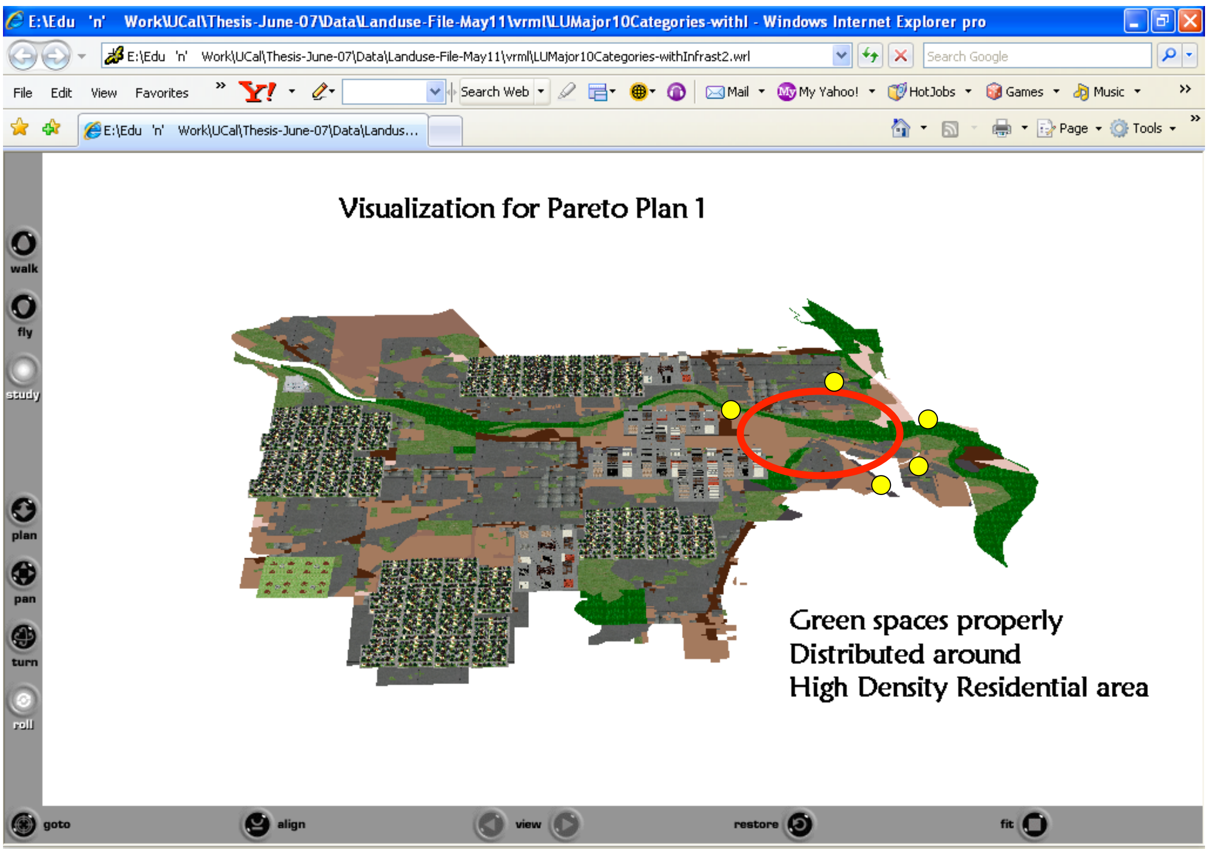
Various components built and integrated into the Scene

Components added to the 3D VRML world

Results and Discussion




A GA-Enable VR Framework For
Generating Alternative 3D Space Configurations
Research Framework
Virtual Objects
Methodology
Results
3D VR Worlds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Visualization for Pareto Plan 1
Green spaces properly
Distributed around
High Density Residential area
walk
fly
study
plan
pan
turn
roll
goto
align
view
restore
fit

Results and Discussion

2 Res- H and 1 Res-L are competing for meager
Green space & public service

Thank You