Goal-oriented MCTS (G-MCTS) for Urban Planning

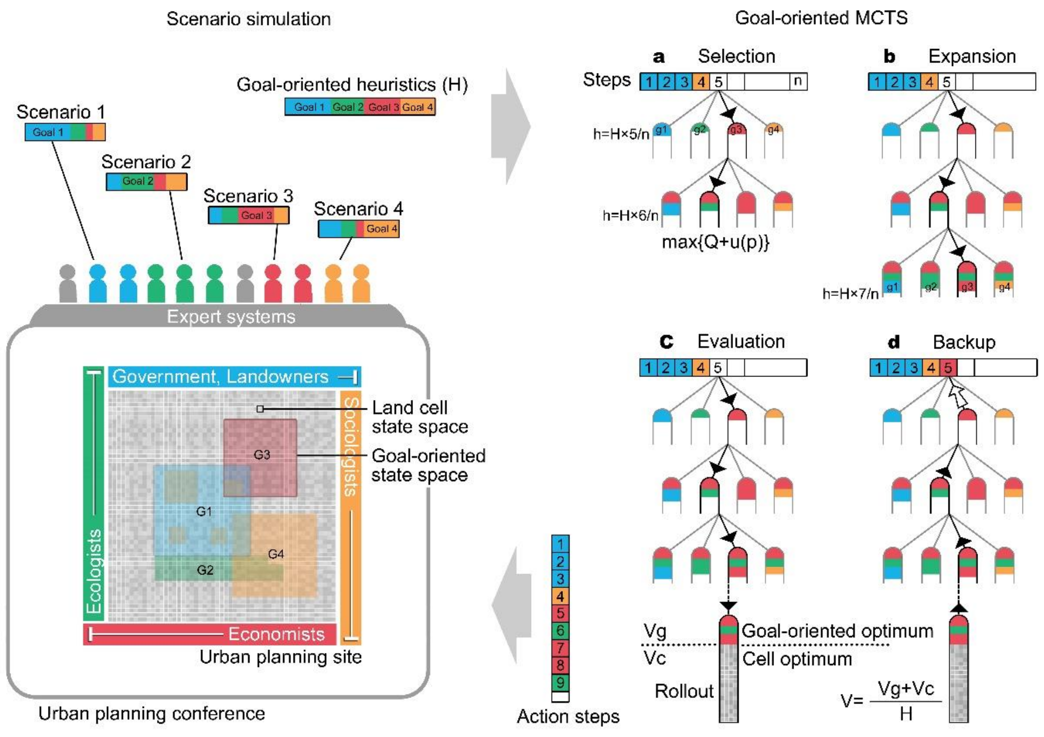
User's Manual

Contents

1. Overview

The development of an artificial intelligence agent with the ability to integrate heterogeneous expert systems and scenarios for complex urban planning issues is challenging. Here, we introduce an artificial intelligence (AI) system with a general systematizing function for democratic decision making by combining the traditional scenario planning with a novel goal-oriented Monte Carlo tree search (G-MCTS) method. The core processes are decomposing goals into subheuristics and substituting land cell rollout searching, which is dominated by the local optimum, with goal-oriented searching, which is dominated by the global optimum, step by step in the G-MCTS. This methodology integrate heterogeneous expert systems with decision makers and build a bridge between subjective computations and objective judgments. Additionally, our planning AI with G-MCTS automatically provides strategies for satisfying multiple goals without deliberate policy programming. In general, we provide an approach for making the most comprehensive planning decisions via human-AI interaction at the political level in complex real-world systems.

1.1 Schematic of the goal-oriented MCTS methodology for urban planning:



The schematic shows the methodology that combines the multiple scenario simulation planning, the high-level goal-oriented heuristic and the novel G-MCTS. In urban planning conferences, experts and decision makers must achieve a compromise among their heterogeneous goals. Our AI system first simulates the scenarios of urban land use changes based on the rules of expert knowledge to obtain goal-oriented heuristics (H) for the subsequent G-MCTS search. The search begins by decomposing the goals into n subheuristics for selection and expansion. The evaluated value V for backup after rollout consists of the goal-oriented optimum value Vg and the land cell optimum value Vc and make a compare with H. As the search proceeds, Vg gradually increases its proportion in V, substituting the Vc step by step in the G-MCTS. Finally, the G-MCTS provides the best sequence of step actions in global optimum for decision makers to fulfill their goals.

1.2 Contents

- GMCTS-UrbanP.exe: the demo software to find the best solution with strategies
- Data: package data for tests and corresponding results

2. System Requirements

2.1 Hardware Requirements

The demo "GMCTS-UrbanP" softwore requires only a standard computer with enough RAM to support the operations defined by a user. For minimal performance, this will be a computer with about 1 GB of RAM. For optimal performance, we recommend a computer with the following specs:

RAM: 8+ GB
CPU: 4+ cores, 3.3+ GHz/core

2.2 Software Requirements

This package is supported for *Windows* operating systems.

3. Installation Guide

The latest version of "GMCTS-UrbanP" software and the user's manual are provided at a download link:
https://github.com/LiangGMCTS/GMCTS-for-Urban-Planning/blob/master/GMCTS-UrbanP.exe.
The demo "GMCTS-UrbanP" software is an EXE that run directly on a computer without need to install.

4. Instructions for Use

4.1 Example data description

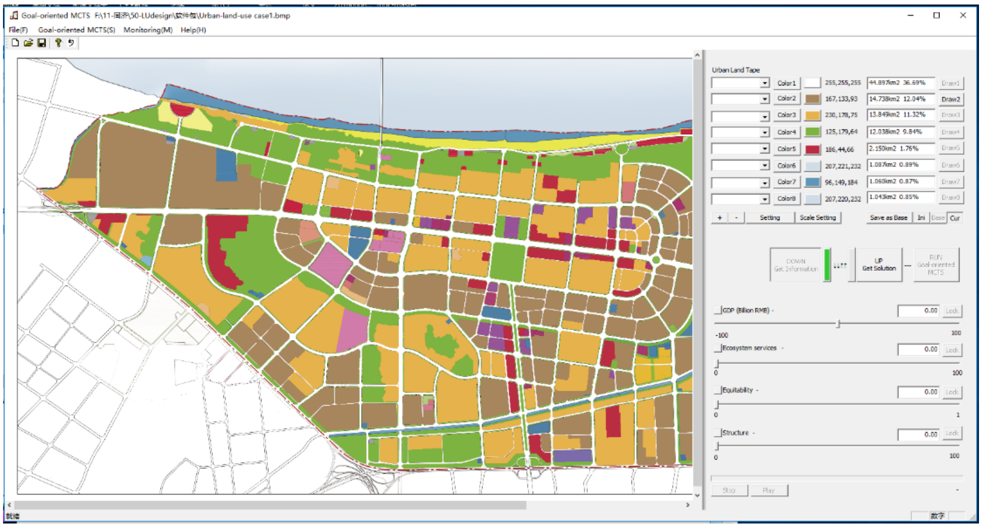
Once the compressed file "Data.rar" (https://github.com/LiangGMCTS/GMCTS-for-Urban-Planning/tree/master/Data) has been inflated, the test dataset are found in the test data folder. Use this dataset to run example model or compared with your simulation results.
The test data "Urban-land-use case1" is a bmp image in which different land usages are in different colors. Each tape of land usage color must use a same RGB based color for the automatic identification. In "Urban-land-use case1", the colors and their types are:

- Urban industrial spaces
- Urban residential spaces
- Urban green spaces
- Urban commercial spaces

4.2 User interfaces of FLUS model

4.2.1 Open a land use image

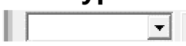
Site images of urban land use are the most indispensable basic data in the urban planning domain. Users are allowed to start urban land use classification by selecting option from the "File/Open file" button on the main menu and open the "Urban-land-use case1.bmp".

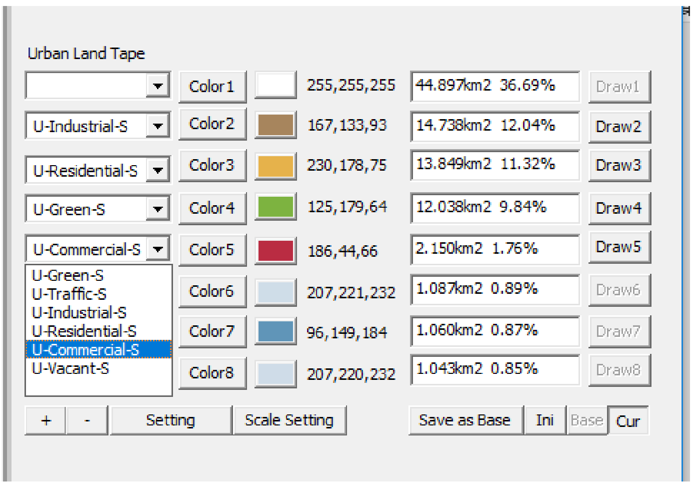


When open the land use image, land colors, areas and percentages are shown on the right top. The entire process for land use solution is controlled by the three processes with three buttons: "DOWN-Get-Information", "UP-Get-Solution" and "RUN-Goal-oriented MCTS". Once users open a land use image, the "DOWN-Get-Information" button is pushed down automatically.

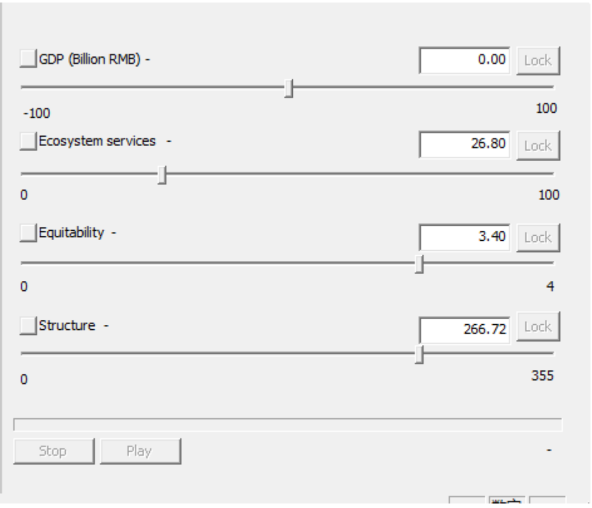
- DOWN-Get-Information: including select land use type function **(4.2.2)** , Sketch function**(4.2.3)** and Monitoring priority images function**(4.2.4)**.
- UP-Get-Solution: simulating scenarios and acquiring goal-oriented heuristics **(4.2.5)**.
- RUN-Goal-oriented MCTS: Using the G-MCTS to determine the best step actions**(4.2.6)**.

4.2.2 Select land use type

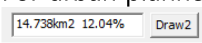
Click the button  in the "Land Use Tape" group box and select the land use type in the pop-up dialog.



When the land use types are selected, the initial four index of goals (GDP, Ecosystem services, Equitability and Structure) are shown in the right bottom.



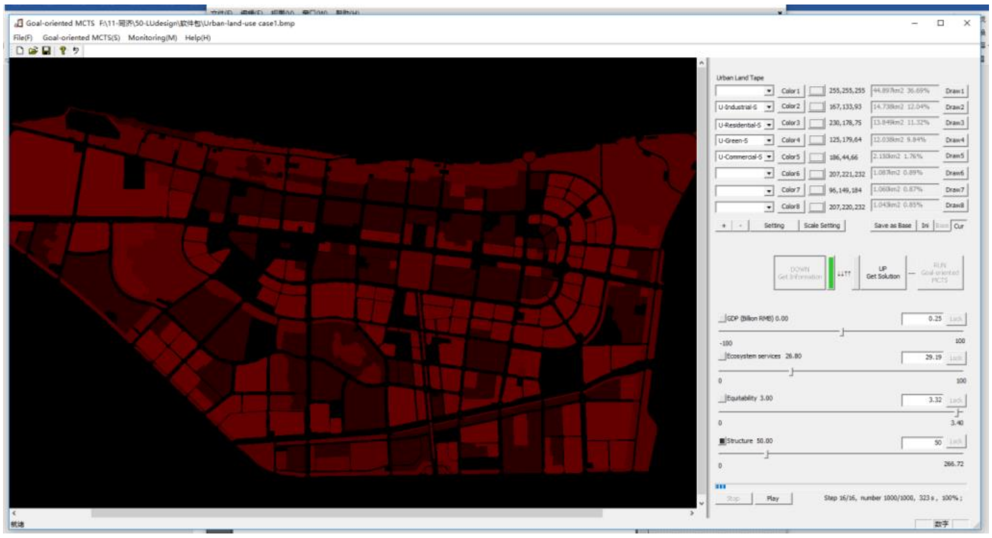
4.2.3 Sketch function (OPTIONAL)

For urban planners, users can get the changes of the four index with the help of draw button 

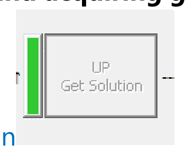
.Click the "Draw" button corresponding one type of land, then paint the land color as a brush on the left image. You can also change the land color using the "Color" button or set the scale using the "Scale Setting" button. The sketch function and these works are optional and not necessary for the following scenario simulation and G-MCTS for solutions.

4.2.4 Monitoring priority images (OPTIONAL)

For experts and decision makers, users can selecting option from the "Monitoring / priority images" button on the main menu to monitor the priorities of each goals. These priorities is rule-based by existing research results or by image recognition

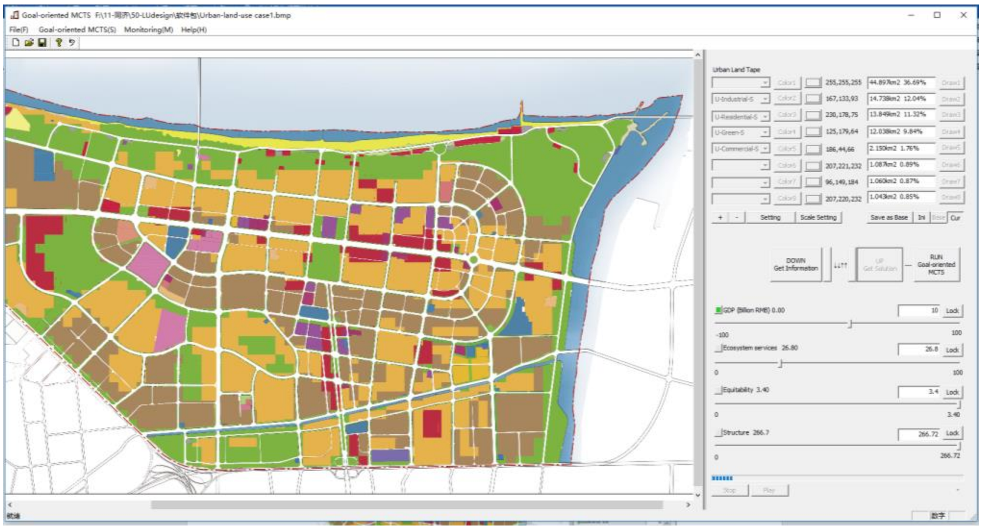


4.2.5 Simulating scenarios and acquiring goal-oriented heuristics

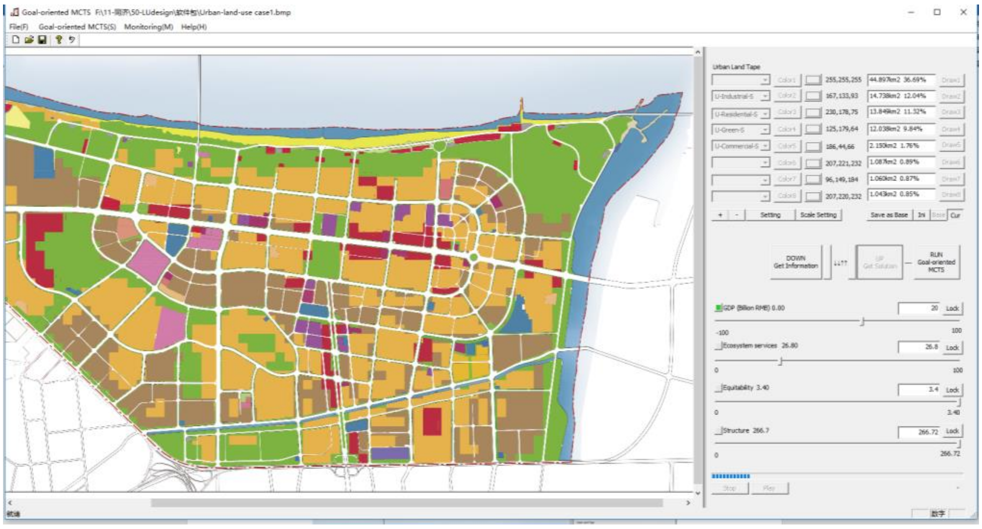
Click the UP-Get-Solution button 

and the scenario simulation begins. Experts and decision makers can enter a number in the edit box and press Enter of keyboard, or drag the scroll bar to acquire the scenario they wanted. The green color of the left means you are working on this goals, for example, 

GDP=10:

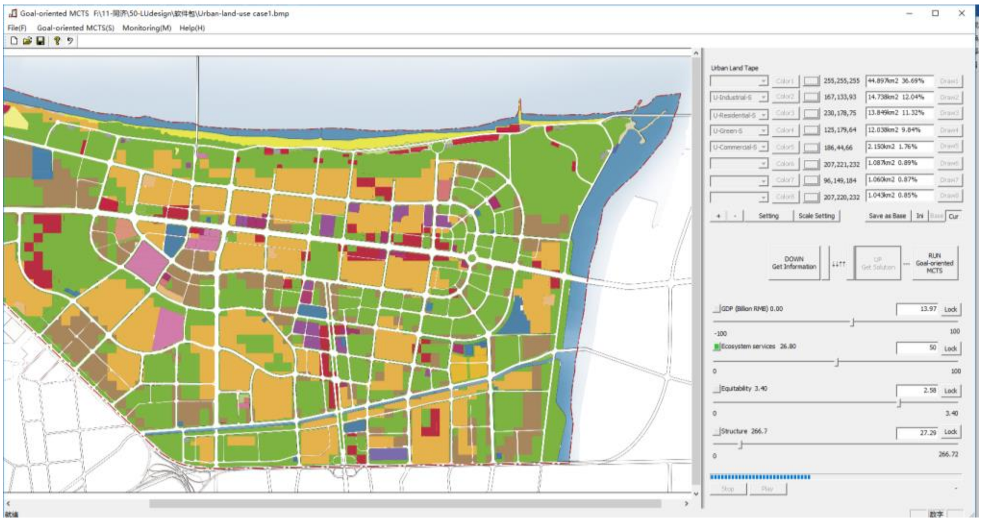


GDP=20:



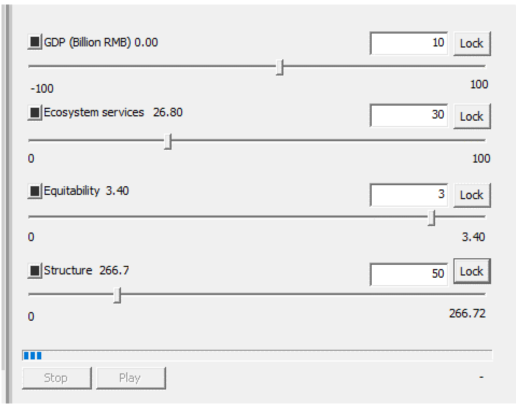
Ecosystem services=30:

Ecosystem services=50:



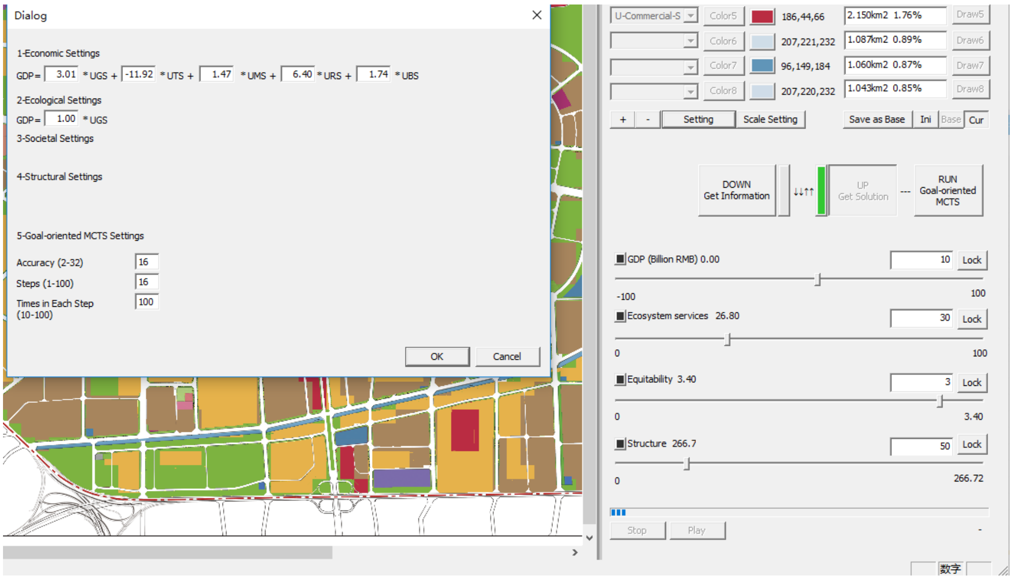
When experts and decision makers achieve a goal in the simulation and they are sure that the result is the scenario they wanted, click the Lock button and the green box in the left will turn to black. After all the goals are lock, the goals and goal-oriented heuristics are acquired. For example,

GDP=0, Ecosystem services=26.8, Equitability=3.40 and Structure=266.72; (Initial index)
GDP=10, Ecosystem services=30, Equitability=3 and Structure=50; (Goals' index)



4.2.6 Using the G-MCTS to determine the best step actions

Click the Setting button to set the G-MCTS' accuracy, steps and search times in each step. For the first run, we suggest to select the accuracy=16, step=16, and times=1000, and click OK button.



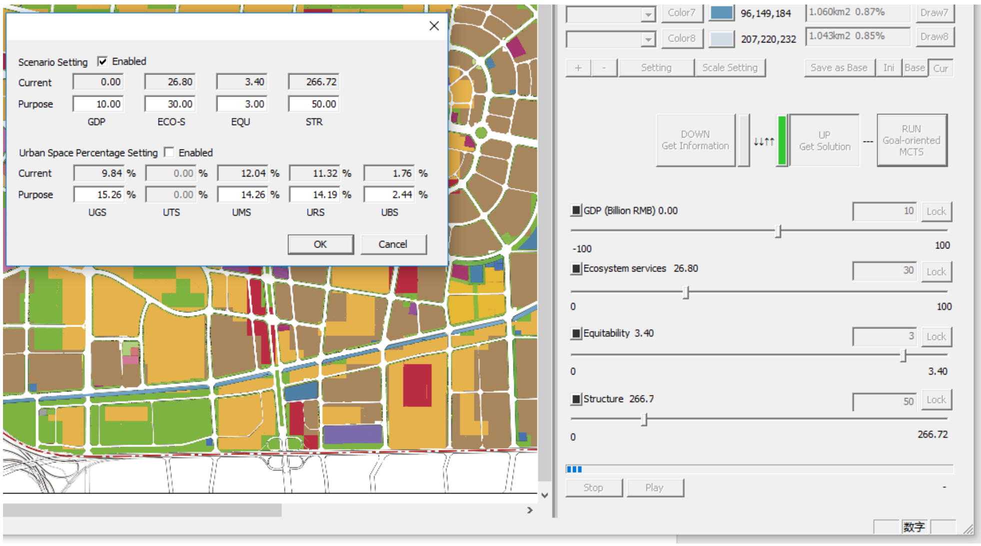
PS: The accuracy and time consumption in different steps' G-MCTS.

Search rounds of a subtree (r)	Total steps (n)														Time consumption (hour)
	1	2	3	4	5	6	8	12	16	24	32	48	64	96	
10	0.921	0.921	0.926	0.929	0.959	0.927	0.958	0.932	0.963	0.963	0.957	0.966	0.959	0.966	Less than 0.1
100	0.921	0.921	0.926	0.937	0.959	0.957	0.969	0.985	0.988	0.962	0.957	0.971	0.959	0.969	0.1-1
1000	--	--	--	0.937	0.953	0.963	0.976	0.983	0.988	0.982	0.989	0.991	0.990	0.994	0.1-1
10000	--	--	--	--	0.953	0.975	0.976	0.984	0.988	0.970	0.990	0.966	0.983	0.965	1-10
100000	--	--	--	--	--	0.975	0.976	0.984	0.988	/	/	/	/	/	More than 10

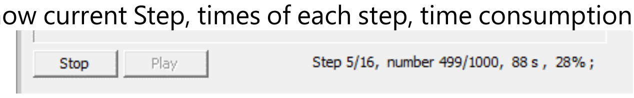
The fulfillment degrees in bold are the best results in each column. The results in yellow shadings reveal that if the search rounds are large enough for the first step' subtree reaching the deepest nth layer, the results are always the best solutions in each column. However, the results in blue shadings indicate that if the search rounds are not sufficient to reach the deepest nth layer limited by computing resources, the results are usually the suboptimal solutions. In this test, the accuracy results shown in red color, when n=8~16 and t=100~1000, are the appropriate settings that balancing the accuracy, search speed and comprehensibility, where the first step's subtree can reach more than a half of the n layers.

Click the RUN-Goal-oriented MCTS button 

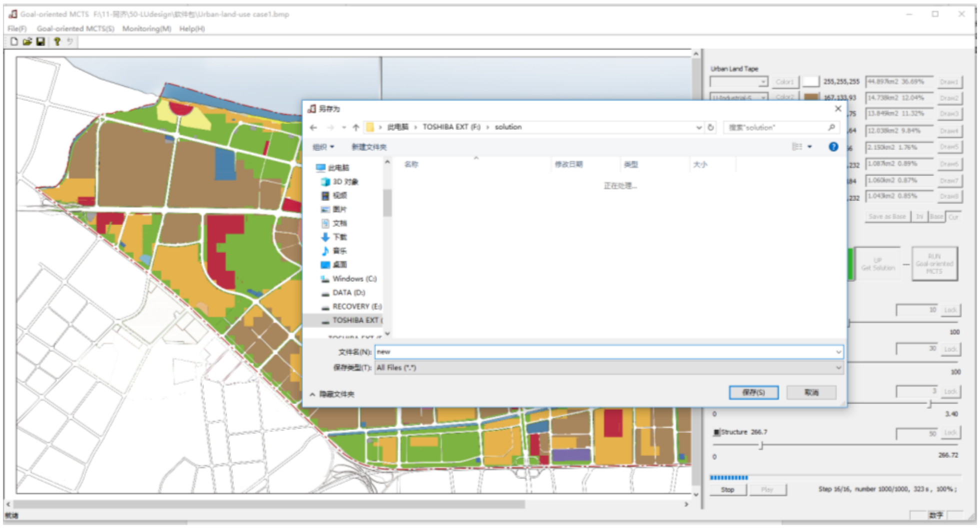
and the G-MCTS will start. Before the final searching, the software asks the experts and decision makers to confirm their goals once again. In this section, users can change the four goals, or add the new goals such as the urban space percentages by enable them. After users click the OK button, the searching begins.



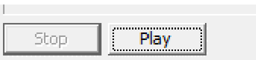
The right bottom show current Step, times of each step, time consumption and rate of progress.



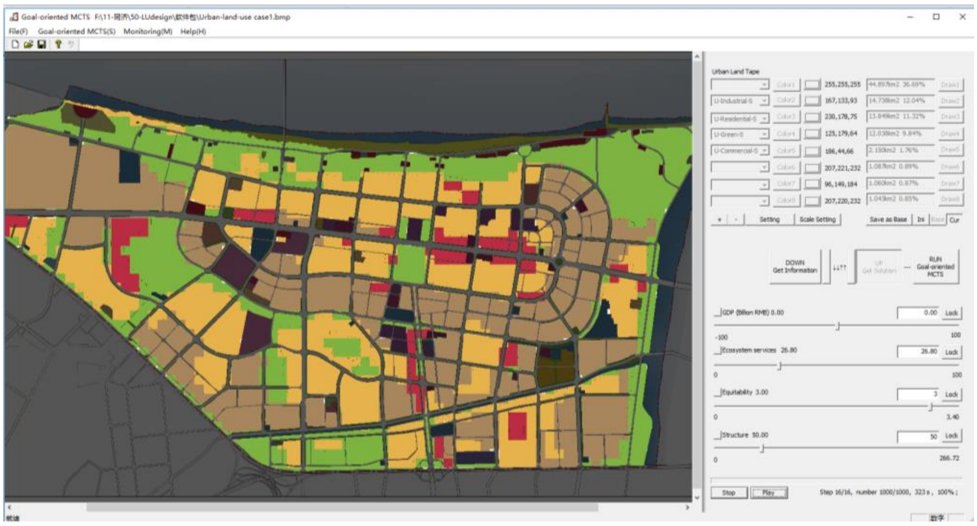
When the searching finished, the software ask to select a file to save the searching results.



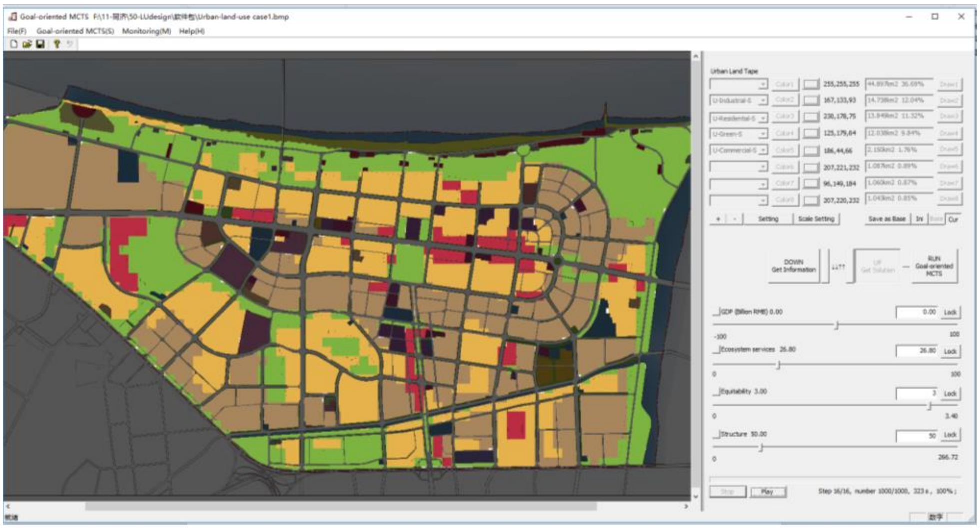
4.2.7 Play the best step actions

Users can click the Play button  to see the best step actions for fulfilling the selected goals. Each step is shown in 1 second:

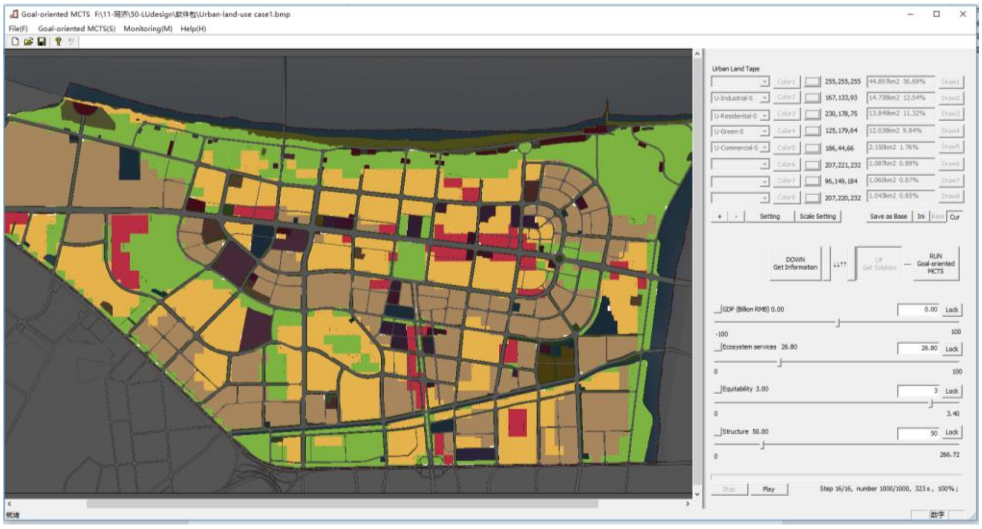
The initial step



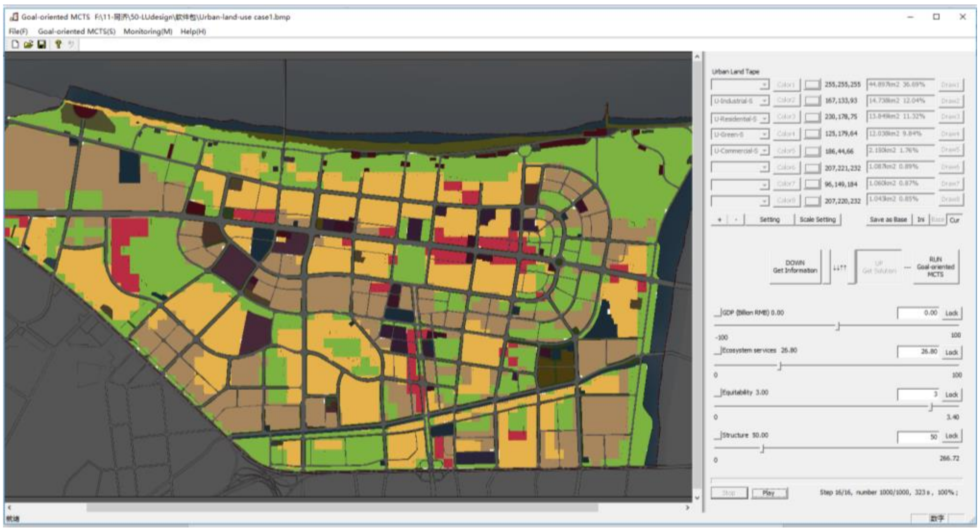
The 5th step



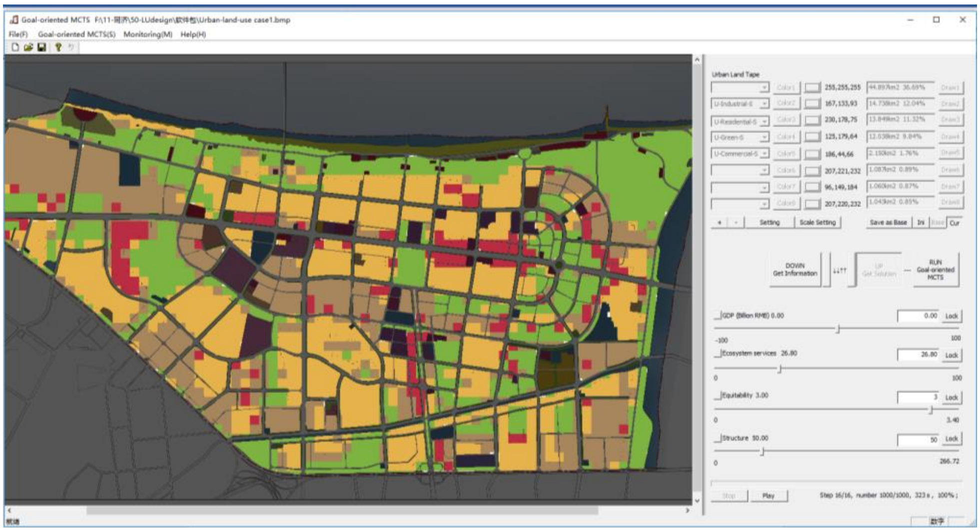
The 10th step



The 13th step

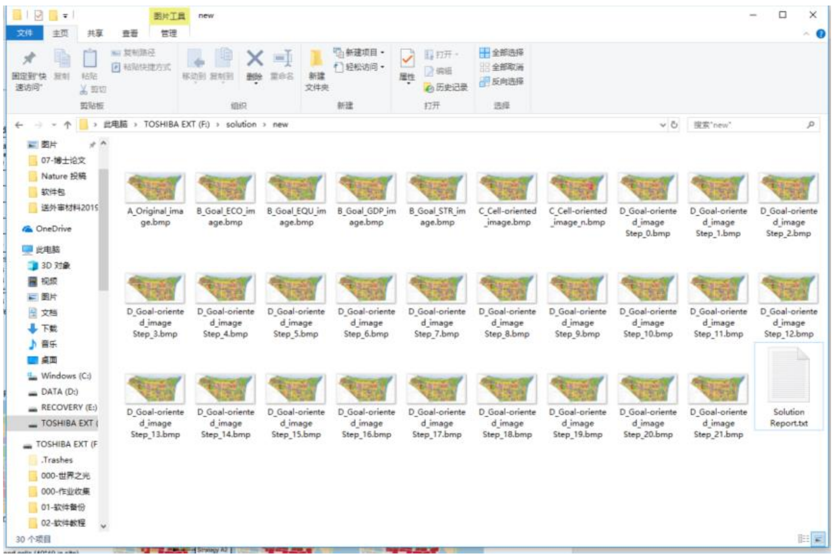


The last step



4.3 Inspect saved results

In the saved file of the results, the original image, four goals' images, step images and a Solution Report is generated.



In the Solution Report, the initial and wanted goals' index, each steps' fulfillment of the goals and the final fulfillment of the goals are shown. In this case, after the 16step-searching, the fulfillment of the four goals is 0.9962.

The Solution Report:

Org; GDP=0.000000; ECO=26.796232; EQU=3.399892; STR=266.718272;

Per; GDP=10.000000; ECO=30.000000; EQU=3.000000; STR=50.000000;

Cell-oriented solution; value=0.4985;

GDP=233.096960; ECO=190.626293; EQU=3.000983; STR=50.732884; US1=0.110150; US2=0.093080; US3=0.126000; US4=0.020300; US5=-9.990000;

GDP=0.11; ECO=1.00; EQU=0.28; STR=1.00; US1=0.22; US2=0.00; US3=0.00; US4=0.00; US5=0.99; 0.60;

Cell-oriented solution; value=0.5951;

GDP=1.071872; ECO=29.987357; EQU=3.287780; STR=50.732884; US1=0.110150; US2=0.110543; US3=0.111273; US4=0.017565; US5=-9.990000;

Goal-oriented solution; step=1; action=3; value=0.8683; step value=0.0300; goal-oriented value=0.4952; cell-oriented value=0.3731; GDP=0.078848; ECO=26.910201; EQU=3.395986; STR=252.268918; US1=0.098789; US2=0.120010; US3=0.113166; US4=0.017565; US5=-9.990000;

Goal-oriented solution; step=2; action=3; value=0.8887; step value=0.0596; goal-oriented value=0.4952; cell-oriented value=0.3936; GDP=0.157696; ECO=27.024169; EQU=3.392060; STR=238.129342; US1=0.099209; US2=0.119590; US3=0.113166; US4=0.017565; US5=-9.990000;

Goal-oriented solution; step=3; action=3; value=0.8991; step value=0.0858; goal-oriented value=0.4952; cell-oriented value=0.4040; GDP=0.110336; ECO=27.138138; EQU=3.388085; STR=224.262847; US1=0.099630; US2=0.119379; US3=0.112956; US4=0.017565; US5=-9.990000;

Goal-oriented solution; step=4; action=3; value=0.9262; step value=0.1147; goal-oriented value=0.4952; cell-oriented value=0.4311; GDP=0.189184; ECO=27.252107; EQU=3.384118; STR=210.759579; US1=0.100051; US2=0.118959; US3=0.112956; US4=0.017565; US5=-9.990000;

Goal-oriented solution; step=5; action=3; value=0.9421; step value=0.1431; goal-oriented value=0.4952; cell-oriented value=0.4470; GDP=0.268032; ECO=27.366076; EQU=3.380144; STR=197.702396; US1=0.100472; US2=0.118538; US3=0.112956; US4=0.017565; US5=-9.990000;

Goal-oriented solution; step=6; action=3; value=0.9590; step value=0.1708; goal-oriented value=0.4952; cell-oriented value=0.4638; GDP=0.346880; ECO=27.480044; EQU=3.376224; STR=185.287680; US1=0.100892; US2=0.118117; US3=0.112956; US4=0.017565; US5=-9.990000;

Goal-oriented solution; step=7; action=3; value=0.9770; step value=0.2109; goal-oriented value=0.4952; cell-oriented value=0.4818; GDP=0.465152; ECO=27.650997; EQU=3.370298; STR=167.791763; US1=0.101524; US2=0.117486; US3=0.112956; US4=0.017565; US5=-9.990000;

Goal-oriented solution; step=8; action=3; value=0.9928; step value=0.2339; goal-oriented value=0.4952; cell-oriented value=0.4976; GDP=0.417792; ECO=27.764966; EQU=3.366400; STR=156.673381; US1=0.101944; US2=0.117275; US3=0.112745; US4=0.017565; US5=-9.990000;

Goal-oriented solution; step=9; action=3; value=0.9952; step value=0.2695; goal-oriented value=0.4952; cell-oriented value=0.5000; GDP=0.409856; ECO=27.935919; EQU=3.360482; STR=140.446925; US1=0.102576; US2=0.116855; US3=0.112535; US4=0.017565; US5=-9.990000;

Goal-oriented solution; step=10; action=3; value=0.9952; step value=0.2943; goal-oriented value=0.4952; cell-oriented value=0.5000; GDP=0.488704; ECO=28.049888; EQU=3.356464; STR=130.500616;

US1=0.102996; US2=0.116434; US3=0.112535; US4=0.017565; US5=-9.990000;

Goal-oriented solution; step=11; action=3; value=0.9952; step value=0.3277; goal-oriented value=0.4952; cell-oriented value=0.5000; GDP=0.480768; ECO=28.220841; EQU=3.350558; STR=116.185425; US1=0.103628; US2=0.116013; US3=0.112325; US4=0.017565; US5=-9.990000;

Goal-oriented solution; step=12; action=3; value=0.9952; step value=0.3574; goal-oriented value=0.4952; cell-oriented value=0.5000; GDP=0.346624; ECO=28.391794; EQU=3.344522; STR=102.307056; US1=0.104259; US2=0.115803; US3=0.111904; US4=0.017565; US5=-9.990000;

Goal-oriented solution; step=13; action=2; value=0.9952; step value=0.3574; goal-oriented value=0.4952; cell-oriented value=0.5000; GDP=4.537856; ECO=35.856747; EQU=3.074314; STR=53.003873; US1=0.131820; US2=0.092449; US3=0.110431; US4=0.014830; US5=-9.990000;

Goal-oriented solution; step=14; action=2; value=0.9952; step value=0.3574; goal-oriented value=0.4952; cell-oriented value=0.5000; GDP=4.758528; ECO=36.540559; EQU=3.049646; STR=53.003873; US1=0.134345; US2=0.090345; US3=0.110010; US4=0.014830; US5=-9.990000;

Goal-oriented solution; step=15; action=1; value=0.9952; step value=0.3574; goal-oriented value=0.4952; cell-oriented value=0.5000; GDP=4.758528; ECO=36.540559; EQU=3.049646; STR=53.003873; US1=0.134345; US2=0.090345; US3=0.110010; US4=0.014830; US5=-9.990000;

Goal-oriented solution; step=16; action=1; value=0.9952; step value=0.3574; goal-oriented value=0.4952; cell-oriented value=0.5000; GDP=4.758528; ECO=36.540559; EQU=3.049646; STR=53.003873; US1=0.134345; US2=0.090345; US3=0.110010; US4=0.014830; US5=-9.990000;

Final solution; value=0.9952; deep max=16 deep_max_dp1=9 deep_max_step=9

GDP=9.919744; ECO=29.987357; EQU=3.000295; STR=51.404751; US1=0.110150; US2=0.089503; US3=0.125579; US4=0.024298; US5=-9.990000;

GDP=0.99; ECO=1.00; EQU=1.00; STR=0.99; US1=0.22; US2=0.00; US3=0.43; US4=0.99; US5=0.99; 1.00;