MULTI-SCALAR AGENT-BASED COMPLEX DESIGN SYSTEMS - THE CASE OF CECO (CLIMATIC-ECOLOGIES) STUDIO

INFORMED GENERATIVE DESIGN SYSTEMS AND PERFORMANCE-DRIVEN DESIGN WORKFLOWS

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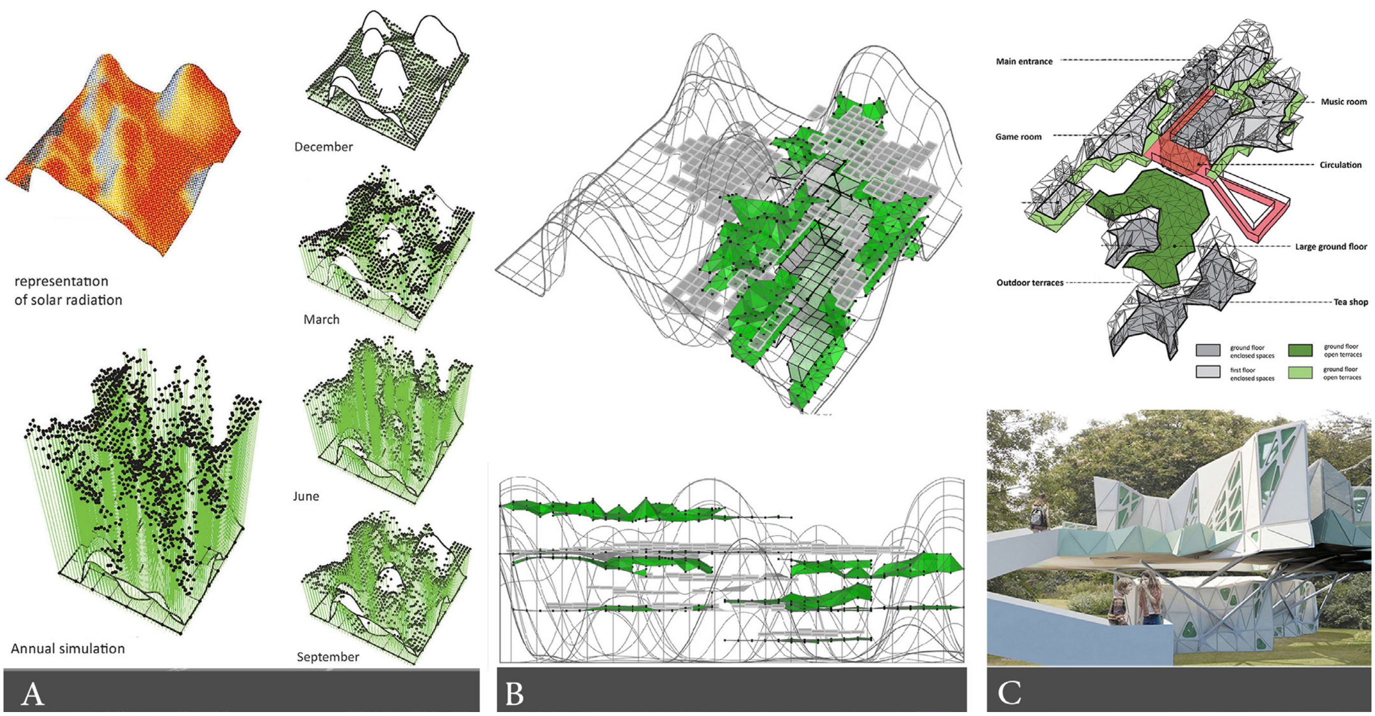


2 Eco-Locator A: Informed point-cloud; B: Snapshots of growth process of the complex system; C: Snapshots of the design outcome

ABSTRACT

This paper illustrates the application of different types of complex systems for digital form finding and design decision making with underlying methodological and pedagogical aims to emphasize performance-driven design solutions via combining generative methods of complex systems with simulation techniques. The design research examples described in the paper are undertaken within the design studio titled CECO or Climatic-Ecologies, conducted at Hyperbody, TU Delft. The computational models explored within the studio include generative systems such as multi-agent system, cellular automata, recursive systems and L-system. The case studies presented in this paper show the early stages of the design development and the use of agent-based system at both macro, urban, scale to micro, architectural and structural scales, while considering environmental and local site conditions.

INTRODUCTION AND BACKGROUND

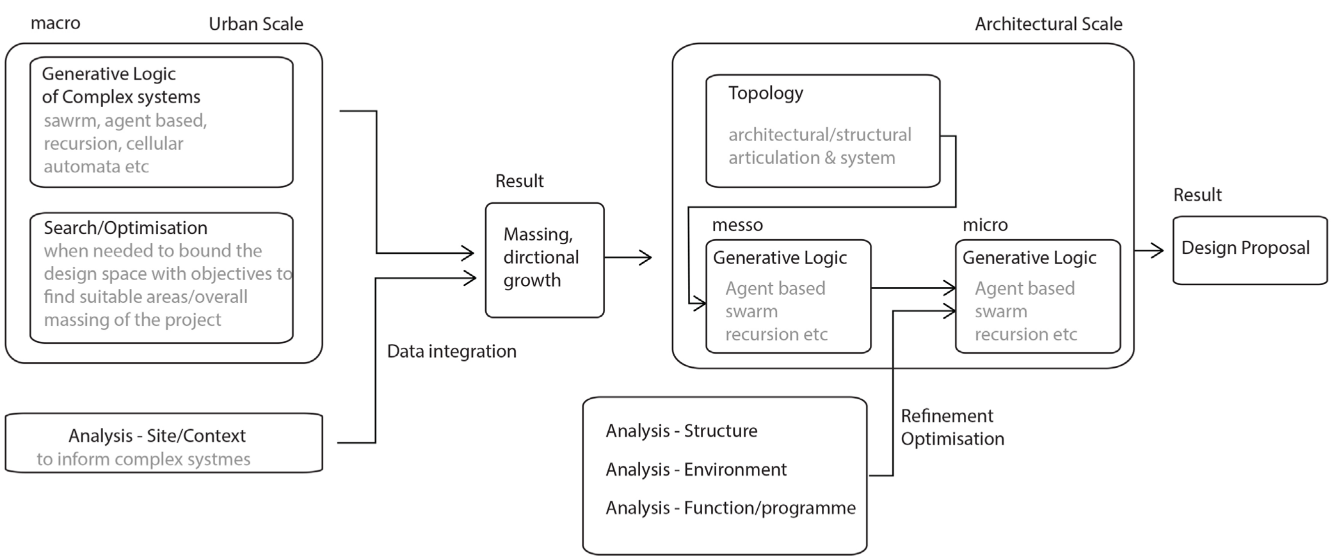
The framework of this research paper is based on deriving strategies for defining computational design workflows by implementing different types of complex systems in order to develop materially and environmentally informed design systems. From the complexity science perspective, complex systems are systems with many interacting components. Complex systems essentially include networks and graphs, cellular automata, agent-based models and swarms, fractals and self-organizing systems, chaotic systems and cybernetic systems (Downey 2011). Considering this definition and the scopes of complexity, the authors have conducted several computational design workshops and an intensive design studio in order to experiment with different types of complex systems to develop computer aided design systems for performance-driven design.

In this paper two main question and objectives shall be explained in more detail: the first is to address one of the fundamental characteristics of Complex Adaptive Systems (CAS), namely Conditional Action. In simple words and in programming, these conditionals can be IF/THEN structures that can define the behavior and characteristics of complex systems (Holland 2006). With this focus, the role of analysis and simulation to inform both: growth environment and the process of self-organization and allocation of architectural functions, elements, entities and materials is considered as one of the eminent factors to structure and develop the design systems. By controlling the behavior of the implemented complex systems, the goal is to tackle this challenge of performative design methodologies which is the way that designers can effectively integrate simulation and optimization techniques with parametric design and generative procedures (Oxman, 2008).

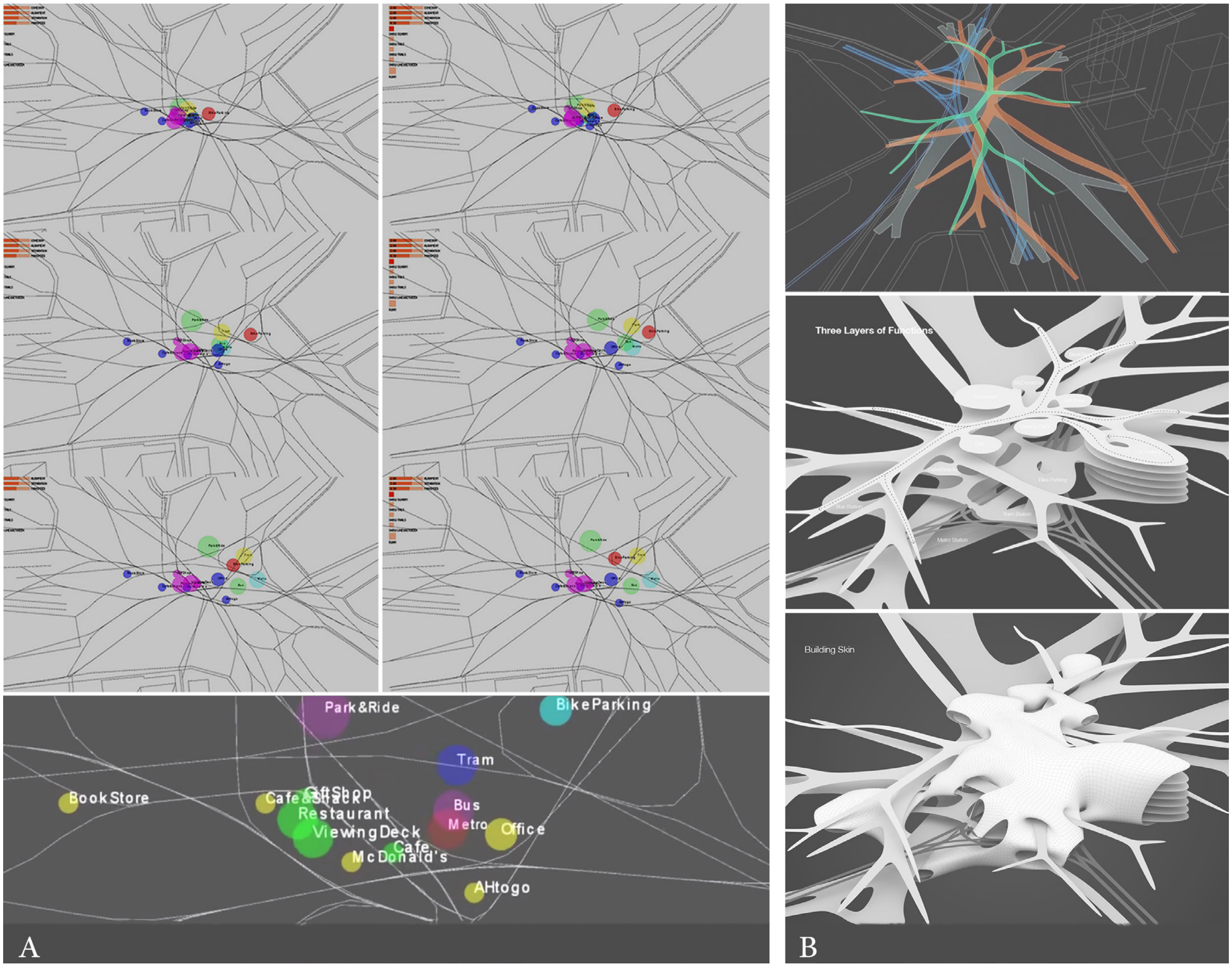
The second objective concerns design information integration and exchange between different stages and scales in the process. This implies that parallel to the studies on behaviors of complex systems, an inclusive algorithm is developed for each of design project in a way that the output set of each sub-routine can be used as the input set for the related sub-system(s) (Mostafavi et al. 2013). With this method the goal is to develop design tools and approaches to support effective knowledge integration in Computer Aided Design (CAD) techniques and methods (Cavieres et al, 2011). For instance the results or output-set of solar radiation analysis or wind simulations will be structured and used as the input-set to inform the growth environment of a specific complex system. Therefore in the studio we tried to implement different types of complex systems based on the defined design goals for each project, considering a holistic guiding algorithm for design information exchange between different stages. A generic overview of the guiding workflow of the studio for controlling data interoperability and integration between different subroutines is illustrated in the (Figure 1). Although based on the design goals and chosen complex systems this model is customized.

INITIAL EXPERIMENTATIONS: COMPUTATIONAL WORKFLOWS AND ANALYTICAL DATA INTEGRATION

The Masters Design Studio: Climatic-Ecologies promotes within the educational framework a relational understanding between physical and climatic principles, computational tools and performance-driven form finding processes. The case studies described in the paper are to emphasize the climatic association between the building and its context as the primary concern of the



1 A generic schematic workflow for design information integration in relation to the complex system in CECO studio



3 Marconiplein Transportation Hub A: Program distribution using Agent-based modelling; B:result configuration

design research topic. In line with this studio theme, the research assignments are designed to integrate simulation techniques and the chosen computation models such as agent-based systems that are informed by the resulting data. These research topics are explored both in group and individual design projects.

For initial phases, the goal is to study the behaviors and characteristics of different types of complex systems. This starts with exploring the potentials for defining and embedding search and evaluation routines with programming inside the CAD and scripting platform to have meaningful control on conditional actions. Then the subsequent goal of the studio is to formulate frameworks for integrating these generative systems within the bigger computational design workflow. These frameworks are suggested to the design teams as guidelines for the overall structure of the design algorithm and computational logic. This algorithm is intended to host all the subsystems including the parameterization module, generative systems, simulation and analysis modules plus their structured results as non-geometric design information, visualization and optimization.

The studio projects include five group and twenty individual design projects, and this paper discusses and compares one of the group and two of the individual projects as case studies. The first case study is based on a group collaboration to investigate a digital workflow to integrate evaluation and optimization routine together with recursive branching system while designing a pavilion within a park. Subsequently, two case studies carried out as individual assignments to explore agent-based modeling in different scales are presented. First, one is at the scale of self-organization of functions and in relation to an urban network system and the second is focused on material distribution and is more at architectural scale.

The group project titled Eco-Locator (Figure 2) has developed a two-fold climatic strategy focused on CFD (Computational-Fluid-Dynamics) for airflow simulation and solar radiation plus daylight access simulations on site. The goal is to provide a data set for all coordination on the site in a way that this information can be accessible for informing the generative system. A recursive search is employed as the generative system to the site condition and to grow into the overall configuration of the pavilion structure, as well as the circulation system that will shape clusters to host the planned program.

CFD simulations are by definition dynamic, therefore a strategy is formulated to transfer relevant data, from Ecotect Vasari, to Rhino through Grasshopper. The strategy consists of creating multiple simulations; one each for dominant seasonal conditions and uses color-coded results to inform a point-cloud. The solar-radiation evaluation of the existing site condition is conducted simultaneously using Diva in Grasshopper. Within the multi-criteria analysis, information layers are associated with each point of the point-cloud, providing a multi-dimensional data-structure, to be used as target population for the complex system.

The first implementation of the branching system on this informed point-cloud produces the circulation scheme of the pavilion, giving another spatial dimension to the data. Secondary branches are then grown into the same point-cloud considering specific geometric constraints, which grow along the body of the main branch and account for the individual clusters as spaces. The team deals with three global work-flow problems: data translation from CFD, the use of genetic solvers to find optimal solutions from a predefined known array of possibilities, and more importantly, developing and controlling of recursive systems in Python as a form-finding tool (effectively steering geometric growth in point-clouds informed by previous steps). In order to capture the dynamic character of conditions regarding airflow, seasonal wind variation is considered in the simulation to visualize the changes in the local conditions to assist decision-making process by constantly re-adjusting the computational tools and the methods. The cyclic nature of the designed computational flow allowed the team to explore the performances of semi-optimal different alternatives for different seasons. This resulted to having the possibility of meaningful intervention to the optimization process by designer.

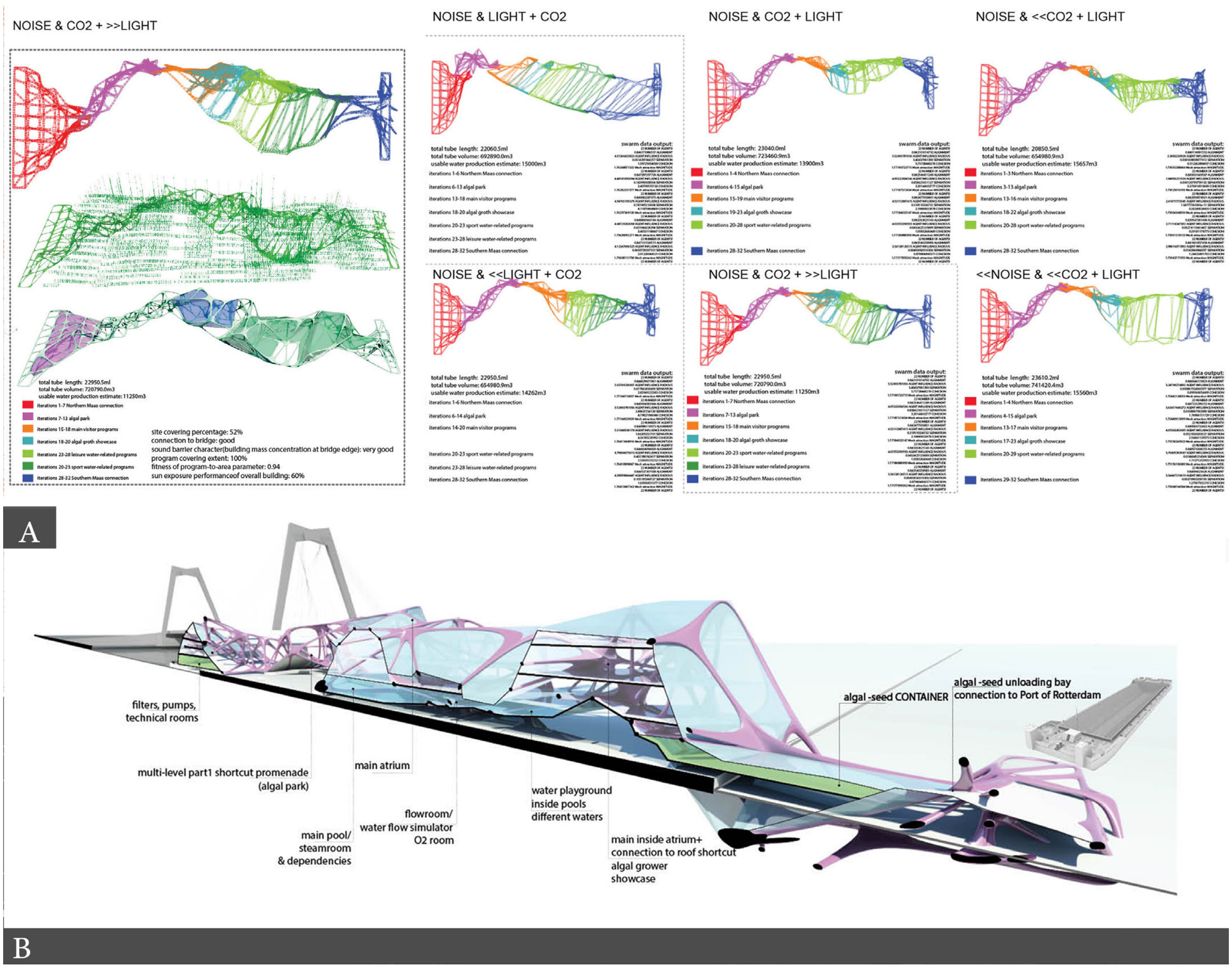
DESIGN INFORMATION INTEGRATION BETWEEN MACRO-MESSO-MICRO SCALES

The project titled Marconiplein Transportation Hub (Figure 3) utilizes agent-based modeling in an urban macro scale. The two main aims are to provide transportation efficiency and to allocate programs where they are suited. In line with this aim the project utilizes the existing infrastructure to inform formal attributes and the program distribution. The selected site is located at the junction where six different streets come together. The proposal considers the exiting street connections, stations and surrounding parks and determines the circulation and locations of different programs on the site.

The overall computational approach is divided into three phases, minimal path algorithm, swarm behavior simulation and morphological formation. The minimal path topology reconnects the exiting street network around the site forming the basis for the internal structure to be built. These steps are divided into different modes of transportation to separate the vehicular access from bike and pedestrians and adjusting the heights of the overlapping passages subsequently separates the overlaps. This process is informed by specific height needed for the infrastructure slope, which is determined by the transportation mode.

Prior to performing the swarm behavior simulation, each agent is determined as individual programs with assigned areas as requirements. The relationships of agents are predefined based on the need for the proximity of the different programs. The agents follow the previously determined pathways to locate programs. The separation and cohesion of the program-agents are based on the context, distance from attractions in the surrounding and internal logic to pair different programs together. The simulation provides the base layout of the programs along the circulation. The final step of the process provides enclosure around the program giving the morphological outcome.

The City-Port-Unit (CPU) project (Figure 4) explores swarm intelligence in an architectural messo scale to inform the direction of growth for truss-like structure to enclose programs considering the environmental aspects of a chosen site in Rotterdam. The data integration is essential to the project and it utilizes existing solar analysis methods as well as customized scripts. The noise



4 City-Port-Unit project, A:snapshots of the developed agent-based design system interface; B:section perspective of the project

level and the potential CO2 level are evaluated according to the proximity to the surrounding roads as well as the geometric characteristic of the topography. The results of these analyses provide data-sets to influence the swarm behavior. The site is abstracted as mesh and the combination of the analytical data sets provide scores for each individual mesh, which an individual agent can occupy. The agents form a point cloud, which is translated to the built structure. The prevailing direction of the swarm movement is determined prior to the experiment to ensure that the proposed structure is able cover the whole length of the site. Based on the analysis data, the agents choose one of the three actions: alignment, cohesion and separation, which define width and depth of the structure.

FUTURE WORKS AND CONCLUSION

The scope for the future work of this research includes further in-depth studies and classification of different types of complex systems and their potentialities in design development. This paper investigates the computational design process to incorporate complex systems such as Agent-based modeling as a form finding process that occurs at the early design stages. The key aspects of the described projects include incorporation of the data driven analytical process in order to inform the behavior of the agents and other equivalent system to inform the growth of the proposed form. The developed models, based on these complex systems such as agent based modeling, are used to tackle specific parts of the project within an overall process. The studies show that for a functional implementation of different types of complex systems like agent-based modeling and simulation in different scales, an inclusive computational design workflow and system would help the designers to have a better control on the process. Concurrently or in advance informing the environments in which agents or the generative systems are moving and evolving to control the conditional actions, can lead to applicable and real-time performance measurements and estimations. Authors are also focusing on applying similar integrated and informed design-to-production methods to address hybridity in material.

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IMAGE CREDITS

Figure 1: Mostafavi, Sina; Biloria, N; Yu, Soungmin (2013), A generic schematic workflow for design information integration in relation to the complex system in CECO studio

Figure 2: MSc3 Design Studio of Hyperbody at TU Delft(2013), Eco-Locator A: Informed point-cloud B: Snapshots of growth process of the complex system C: Snapshots of the design outcome

Figure 3: MSc3 Design Studio of Hyperbody at TU Delft(2013), Marconiplein Transportation Hub A: Program distribution using Agent-based modelling; B:result configuration

Figure 4: MSc3 Design Studio of Hyperbody at TU Delft(2013), City-Port-Unit project, A:snapshots of the developed agent-based design system interface B:section perspective of the project

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