Emergent Ecology:

Creating Inclusive Cities Through Speculative Interaction.

A 120 point thesis submitted
to Victoria University of Wellington in partial
fulfilment of the requirements for the degree
of Master of Architecture (Professional).

Victoria University of Wellington
School of Architecture

2018

Shaneel Kumar

Acknowledgements.

This thesis would not have been possible without support and guidance from academic staff, fellow students, friends and my family during this final stage of my university career.

I would like to begin by thanking my supervisor Derek Kawiti who has offered an incredible wealth of knowledge, expertise and encouraged me to stay confident during times of uncertainty whilst undergoing this research. I would not have been able to learn and accomplish what I have without your guidance.

I would like to acknowledge friends and fellow peers who've kept up an interest in my research and tried to sympathize with the many trials and tribulations that occurred throughout the year. The constant support between each other is what kept all of us going through uncertain times and will be a fond memory when I look back at our time as students.

Finally, I would like to thank my family for being patient with me throughout the last 5 years of this journey. There were times that I could not make it home as often as I should of and I thank you for being so understanding.

Abstract.

Many cities within developing countries are facing an increased demand for space to work and live as contemporary top-down urbanisation strains to facilitate the rising urban population. Future projections estimate that the world's population will transition from rural to urban living within a relatively short period of time, causing concern towards transition and facilitation of culturally specific demographics and their values within the existing socioeconomic condition of a city. This research proposes a speculative bottom-up approach to urban design which utilises the behavioural tendencies of various demographics within a cultural context to inform how a city can facilitate inclusivity through diverse social and economic interaction. Inclusive cities are paramount to the socioeconomic success of developing countries, with the potential to provide over 80% of the country's economic growth.

This investigation looks at New Delhi, India as a context within which to test the proposed emergent model for urban design (behaviour driven approach) using a simulation based methodology to test how New Delhi's various demographics can diversely interact to invoke an inclusive future city in response. The speculative design investigation of this research will highlight the potential of bottom-up urban design and the merit of using behaviour-based, emergent methodologies for urban planning, creating diverse interaction and an alternative to contemporary top-down urban planning.

The aim of the research is to develop a methodology for simulating how agent behaviour can be utilised to inform urban design. The methodology will simulate an urban population by utilising individual and collective behaviour to inform the organisation of density within an urban scale. The data will form a "pre-geometry state" in which typology, infrastructure and other key nodes can be instanced to create an emergent, urban ecology informed by agent interactions.

Contents.

Introduction.

Cities within developing countries are facing an increased demand for space to work and live as population growth and transition from rural to urban living occurs within a relatively short period of time. This issue has been highlighted by the United Nations within their "New Urban Agenda", a manifesto that responds to the rise in urban population numbers through various agenda's that developing cities can adopt. As young cities begin to develop exponentially due to rising population numbers, the opportunity for these cities to become significant social and economic hubs becomes increasingly important for prosperity, an opportunity which the United Nations have suggested be capitalised on using their "New Urban Agenda" manifesto. A primary agenda suggested by the manifesto places emphasis on diverse social and economic interaction that various demographic types can capitalise on and subsequently, contribute to the growth prosperity of their developing city.

Research Question:

This research proposal asks whether a speculative bottom-up approach to urban design can be used to challenge traditional, top-down planning of cities by creating urban environments that foster inclusivity through diverse social and economic interaction, explored by simulating the behavioural tendencies and interactions of a city's population through digital methodologies.

The aim of this design research is to develop an emergent, agent based methodology that simulates the behaviours and interactions of a specific urban population and utilises the resulting emergent properties to inform bottom-up, behaviour-driven urban design solutions that are inclusive. Existing urban elements will be given agency to react to agents, allowing agent – environment interactions. This methodology will be developed for computational simulation through agent-based modelling in which qualitative behaviours for various demographic types and urban elements will be prescribed through experimentation and iterative testing to observe changes to their collective behaviour and the interaction of agents over time. Through design experiments, the agent-based methodology will be developed to respond to the context of New Delhi and its diverse urban population. A final simulation will inform a developed design that organises typology, infrastructure and other relevant urban elements into an emergent design solution that responds to the collective behaviour of its population and encourages diverse interaction by forming spatial relationships between elements organised within this process.

The primary objective of this design research is to unpack the behaviour of New Delhi's diverse urban population and influence of social and economic landmarks on population behaviour and interaction. Both urban population and socioeconomic landmark have the potential to be assigned agency, however, come with a set of challenges that have to be overcome. Behaviour, as a qualitative attribute of an individual will be abstracted into quantitative parameters that can be adjusted and controlled computationally. This will require abstract assignment of behaviour(s) using quantitative values as a means to control intensity and change in behaviour. A timeline of interactions can be made possible by tracking agent trajectories over time and observing moments of interaction over the course of an agent's life within a digital environment. Assignment of agent behaviour within a digital environment will be the first objective of the design research, and in particular, the abstraction of qualitative behaviour into quantitative parameters.

Assigning agency to landmark urban elements will be explored through digital artefacts within simulation space. Digital artefacts will represent an external and environmental influencer to agent behaviour and will operate through proximity. To a lesser extent, assigning agency to digital artefacts will require similar abstractions of behaviour, similar to the first objective. Exploring digital artefacts will be a secondary objective during the preliminary and developed design phase of this investigation.

The final objective of this research will be to explore self-organisation of urban elements such as infrastructure, typology and other elements to manifest an urban environment that responds to the collective behaviour of agents. This final objective will be tested and developed within the agent-based methodology by allowing the collective behaviour of agents to inform areas in which urban elements can optimally operate and organise within to facilitate increased levels of interaction between agents.

Design Methods and Process.

Theorists in architecture have often developed separate movements within the scope of Parametricism, a digital methodology in which computational form finding and optimisation is iteratively tested to fine tune design solutions and test new fabrication technologies within the industry. The following theorists have been selected to inform the theoretical foundation of this research due to their involvement and contributions within the Parametricism 2.0 movement which prioritises social functionality, a primary subject of investigation within this research.

Patrik Schumacher is an architectural practitioner, theorist and partner at Zaha Hadid architects who promotes the architectural style of Parametricism as the primary movement for developing architecture in a modern society as complex as the one today. Within the practice are various design research groups that explore the extent to which parametric computation can influence product design and architecture, from large district urban developments to optimised and unique details made possible through new fabrication technologies. Schumacher is a primary theorist and practitioner spear-heading the movement of Parametricism 2.0 whose manifesto and essays regarding the responsibility of social functionality within architecture will form the theoretical foundation of this research. Within recent publications, Schumacher has suggested Parametricism move forward into an evolved movement that priorities social functionality as a parameter for designing architecture. The evolved movement coined Parametricism 2.0 brings with it a new set of theories and exemplars that can be used as the theoretical foundation of this research. In particular, Schumacher suggests agent-based modelling as a tool for testing social functionality through parameter driven simulations, a methodology which this research intends to develop and explore.

Emanuel Delanda is a social theorist who has contributed significantly to many disciplines, including architecture and quite recently, the movement of Parametricism 2.0. Delanda has contributed to Schumacher's movement through prescription of an adapted social framework known as assemblage theory that looks at the emergent property of collective interaction. Delanda contributes to the theoretical foundation of this research by prescribing specific means to utilise assemblage theory through parameters, aligning the theory towards Parametricism 2.0 and its priority towards social functionality. Prescribed with

Delanda's assemblage theory adaptation are parameters that can be controlled to test the social functionality of digitally designed environments through spatial legibility and any emergent properties which may occur through agent-based modelling. This research aims to test and build upon Delanda's prescription by testing new social parameters that can be controlled within a developing agent-based methodology, grounded within New Delhi's context and urban population behaviour.

Scope of Research.

This design research sets out to achieve a speculative urban design scheme that is emergent and responsive to the urban population of New Delhi while being inclusive of their social and economic behaviours and interactions. The speculative nature of this research will lead to an abstract design solution, however the primary objective of this investigation is to explore the notion of behaviour driven, bottom-up design of urban environments through its developed methodology. The scale of the design investigation is a limitation in regard to how specific and detailed the final design solution will be. The scale requires a portion of New Delhi's urban fabric to be erased to allow the project to embed itself into the city and its context. Beyond the scope of this project are elements of detail that operate outside the scale of an urban development master plan. This limitation will affect the micro resolution of design experiments which do not fall within relationship and organisation of typologies, infrastructure and other large urban elements which operate at a macro scale.

Thesis Structure

Site/Context Analysis.

Analysis of New Delhi's socioeconomic context will be vital to understanding how the city and its inhabitants operate through behavior and how their urban environment can manifest in the future to accommodate rise in urban population and develop diverse socioeconomic interaction. This context analysis will look at New Delhi's future planning for social and economic development to extrapolate values with which to inform the starting parameters of culture specific, agent-based modelling. Delhi's 2021 master plan will be analyzed to develop a stance on New Delhi's immediate urban design goals and the extent to which inclusivity is prioritized. The existing urban environment will be analyzed to highlight existing social and economic hubs which maintain diverse interaction, preserves the city's characteristic and can be utilized as environmental influencers to inform socioeconomic agency within existing urban elements. Behavior(s) will be extrapolated from demographic analysis of New Delhi's census to define how agents can behave within a digital environment to manifest collective intelligence, a pre-geometry state of information used to inform context specific design development.

Urban Plan Agenda.

The DDA (Delhi Development Authority) (2007) have defined urban design as "an assemblage of buildings and streets, systems of communication and utilities, places of work, transportation, leisure and meeting places. The process of arranging these elements both functionally and beautifully" being the essence of urban development (p. 104). Created by the DDA, Delhi's 2021 master plan outlines the various steps being taken to improve the development of New Delhi city regarding increased urban population numbers as well as changes in employment preferences and industry. The developmental goals of New Delhi city will be addressed through context specific design experiments that will imbed agent-based modelling iterations into district specific contexts.

Visual integration is outlined as a priority to retain "strong visual identity" of its various towns and city, all of which feature "tremendous diversity of built form, color, scale and texture with a heterogeneous end product" that is characteristic from a design standpoint (DDA, 2007, p. 106). Additionally, the DDA have outlined the importance of various circulation pathways running through Delhi such as monorail train stations (MRTS) outer ring roads and other major radials which the urban population rely on to navigate through and around the city. New MRTS and roads have the "potential to acquire an additional dimension of visual quality and integration" (DDA, 2007, p. 106) that can contribute to the characteristic and spatial legibility of the city. This research places emphasis on creating "social organization via spatial organization" (Schumacher, 2016, p. 109) and will aim to visually integrate newly created forms and infrastructure with outlined recommendations to create spatial legibility, built upon through design development.

Figure 0.1: Red Fort, Delhi.
Distinct visual characteristic of Delhi.
Image by: Savin, A.

Social Analysis and Agenda.

Social infrastructure within New Delhi aims to provide a framework of functions which improves the general health, education and livability of the urban population. The DDA have outlined a strain on existing social infrastructure due to an increase in urban population numbers which continue to rise, an issue they aim to address within the master plan. As space for both commercial and social development become more limited within New Delhi, the DDA (2007) have outlined (in response) a set of "norms and standards" (p. 137) for new social infrastructure that outlines parameters within which specific social developments can operate. Social developments encouraged by the DDA look at creating new education and sports facilities, social events and recreational facilities which will help alleviate strain on social infrastructure due to increasing urban population. New educational developments are encouraged to facilitate mixed-use functionality which integrates similar infrastructure that overlaps and operates to facilitate various education developmental brackets during different times of the day. The DDA (2007) have stated priority towards mixed-use educational developments as an efficient response to increased social demand as specialized facilities are required more than ever whilst existing standard education facilities remain under-utilized, at least to their maximum potential (p. 137).

Sports facilities and stadiums are also encouraged to "establish the capital city as a sports center for major events" (DDA, 2007, p. 140) and to increase the social identity of New Delhi by being able to host district, national and international level sporting events, the commonwealth games being an example. New sports facilities are encouraged to be mixed-use to allow diverse use of facilities, leading to efficient use of land. Mixed-use developments are being recommended by the DDA in response to the underutilization of existing sports stadiums and facilities. Due to the specificity of their function, the specialized infrastructure these facilities provide tend to accommodate specific levels of utilization, ranging from district school tournaments to national sporting events that draw in large crowds. Between the two ends of the spectrum exists very little opportunity for medium range facilities to operate due to under or over utilization. The DDA (2007) therefore encourage future developments to be of mixed-use infrastructure to accommodate a range of sporting events as well as occasions and performances which require larger venues with more seating than the standard auditorium or theatre (p. 140).

Social infrastructure for socio-cultural activities are encouraged by the DDA (2007) through development of banquet halls and auditoriums that facilitate community activity and participation through weddings, local performances and annual cultural events. Operating at a neighborhood scale, these smaller facilities are encouraged to be multi-purpose to accommodate a multitude of functions allowing various events to take place locally, bringing communities together (p. 147).

Economic Analysis and Agenda.

Industries within New Delhi face a variety of challenges dues to rising urban population numbers, causing pressure for new and existing developments to use land efficiently and maintain environmentally friendly practice. The agenda for industry as outlined by the DDA (2007 aims to mitigate the environmental impact of businesses and relocate industries that operate within illegal land-use zones to appropriate sectors where their respective functions are permissible (p. 67). Modernization of existing industries is specified over creation of new developments to diminish changes to land-use zoning laws and permissible functions within respective zones. New industry development will be permitted for "hi-tech" (DDA, 2007, p. 67) industries which are otherwise scarce and will be efficiently accommodated within newly developed land-use zones. The "flatted factory" (DDA, 2007, p. 69) typology is suggested for new industrial developments as a modern approach to factory assembly and manufacturing in which vertically layered factories share common machinery, resources and storage space to maximize space and infrastructure efficiency without requiring horizontal development of otherwise large industrial blocks.

New Delhi's urban population face an economic crisis as household industry becomes increasingly common as a primary source of income for the lower class population. Household industry is defined by the DDA (2007) as a business that operates out of a worker's household and provides goods and/or services within the neighborhood or city block (p. 67). These industries intentionally do not adhere to health, safety, pollution and land-use standards due to improper regulation and the spontaneous rate at which these family owned businesses pop up off the record (DDA, 2007, p. 67). Typically, these businesses are run by a maximum of 5 people and operate within the streets of lower-class residential areas. The DDA (2007) have outlined an agenda that makes household industries permissible by widening the scope of regulations required for these businesses to operate within if they adhere to local protocols to regulate pollution, have consideration for the environment and maintain proper utilization of surrounding infrastructure (p. 69).

Conclusion.

The social and economic considerations outlined within this analysis will be utilized within the developed design stage of this research to make context and agenda specific considerations towards required urban typologies that respond to the DDA's social and economic concerns whilst operating within an established theoretical framework and agent-based design methodology. An equal emphasis will be placed on growth for both formal and informal industries within the developed design stage by exploring typologies and arrangements within the ecology that facilitate both types of businesses and their respective agent interactions.

Recent amendments were made to clause 7.4 of Delhi's 2021 master plan which changed the definition of household industry as recognized by the DDA. The definition saw a change of acknowledgement from a maximum of 5 man operations to 10 man. This amendment was brought forward by a member of Delhi's BJP party, Manoj Tiwari who sought to include a wider scope of household businesses that operate within the city to allow for increased growth through permissibility and provision of adequate infrastructure (The Pioneer, 2018, para.1).

Figure 0.2: Connaught Place.
Iconic social and economic centre of New Delhi.

Figure 0.3: Cellular Automata Variation.
Mathematical depiction of assemblage theory and emergence within a collective whole.

Parametricism 2.0

Social functionality within the movement of Parametricism 2.0 forms the theoretical foundation of this research and its aims and objectives. Parametric computation allows the iterative testing and refinement of spatial environments using abstract social parameters as input data. The following chapter reviews the movement of Parametricism 2.0, outlined by Patrik Schumacher and other contemporaries as they disseminate how the movement can evolve by shifting priority towards social functionality. This shift begins by positioning social functionality within the process of parametric computation and in particular, how social frameworks can be parametrised to operate within a digital environment.

Before disseminating how Parametricism 2.0 intends to parametrise social functionality, Schumacher first explains why the movement intends to shift its priority. As an architectural style, Parametricism has endured an uphill battle of criticism since inception, evident within the criticism of works by Zaha Hadid, Frank Gehry and Greg Lynn who've tested the limits of architectural expression and new construction and engineering technologies to produce complex structures and unimaginable forms that have not been received well by practitioners of the discipline. In response to this new architectural style came criticism from practitioners opposed to the "expressions of technophilic exuberance" which gained traction during the economic recession of 2008 and has since been associated with "self-indulgence" (Schumacher, 2016, p. 10).

In response to this criticism, Schumacher (2016) proposes a shift in agenda towards a "focus on social performance," a necessary shift "if the movement is to mature, go mainstream and be accepted as a serious contender for global best practice" (p. 10). Social functionality affects the complexity of interactions between members and "has reached a level of complexity" that Parametricism 2.0 is equipped to handle, stating that "new societal complexity calls for urban and architectural complexity" (Schumacher, 2016, p. 9). The movement and associated architectural style has previously proven its ability to optimise the integration of complex innovations into architectural design and process and aims to reinvent itself again by shifting priority towards social functionality.

Social functionality has been an issue that this discipline has tried to solve using semiology, the process of signifying signs and symbols to assign meaning and social perception within the built environment. Schumacher (2016) argues that past attempts at integrating semiotics into architecture have fallen short due to a lack of constraint, an issue he aims to addressing within the Parametricism 2.0 manifesto which introduces an agent-based, parametric semiology that describes how a social framework can exist within a digital environment (p. 110). Semiotics is a philosophical theory that examines signs and symbols and their associated function within artificial and natural languages. Schumacher (2016) elaborates on the potential of semiotics within architecture and how it can help the built environment to communicate social functionality to occupants by becoming “a system of signification that communicates complex spatial structure and diverse programmatic contents to a multitude of interrelated groups” (p. 109). Communication of complex spatial structures is paramount to Schumacher’s notion of an agent-based parametric semiology in which the communicative capacity of architecture is prioritised as the primary link to social functionality, stating that social organisation is achieved through spatial organisation. Subsequently, the desired social interaction of a space falls “on the participant’s successful orientation and navigation within the designed environment” (Schumacher, 2016, p. 109).

Schumacher (2016) explains the concept of “sign radicals” (p. 111) as physical elements within the built environment that form the architectural signs and symbols which communicate the spatial and physical language of architecture. Individually, sign radicals do not form an indication of social functionality within architecture unless experienced within a territory that specifically communicates it. Schumacher (2016) defines “territory” as the minimal unit of communication, formed by multiple sign radicals as a coherent spatial language that demarcates an intended social function and gives participates the opportunity to partake within the social condition, communicated by the corresponding territory (p. 111).

Parametricism 2.0 can use this theoretical foundation to establish an agent-based parametric semiology to catalyse social design through its communicative potential and test it against success criterion using agent-based modelling. Agent-based modelling can be used by designers to test the "representation of the meaning of the designed architectural communications within a design model," operationalising the role of social functionality within digital architecture through parametric methodologies (Schumacher, 2016, p. 112).

Agent-based modelling operates by assigning behavioural traits to agents and testing interaction between agents and their environment (territory) through iteration and refinement over time to stabilise the collective interaction of an agent population within a localised and context specific environment. Schumacher (2016) states that the ability to change in behaviour as agents enter new territories while having the capacity to choose to participate, determined by a pre-set of behavioural tendencies allows agent-based modelling to critically test the social functionality of an architectural model through variable agent types that have choice over participation (p. 112). The threshold between territories implies different social functions within their corresponding environments and collection of sign radicals whilst behavioural variability gives agents choice over participation according to their individual behavioural tendencies. These two attributes of an agent-based methodology allow social functionality to catalyse within its digital environment.

Designed territories and sign radicals can be tested through agent-based modelling to evaluate the social functionality of the design against pre-established success criterion. Success criterion can change from project to project, however Schumacher (2016) proposes establishing conditions of evaluation that compare the results of simulation against criteria such as "density, diversity, relevancy and quality of interaction scenarios" (p. 109). Evaluation of an architectural model against its communicative capacity allows the methodology to iterate and refine its spatial legibility by determining changes in parameter to make iterations more successful, a condition determined by the pre-determined success criterion that is established at the beginning of the project.

Parametricising the Social.

Social functionality has been theorised within the discipline of philosophy as an understanding of individuals and society, as well as other social constructs in between. Emanuel Delanda's modified theory on assemblages, a theory originally coined within "A Thousand Plateaus" by Gilles Deleuze and Felix Guttari (1980), reveals the complexity of social constructs and their ability to develop emergent properties through consistent interaction between parts of a whole.

Delanda (2016) recommends Parametricism 2.0, as a methodology with an agenda, frame social constructs within a meso-scale, encapsulating everything from the individual to society as a whole (p. 124). The meso-scale is said to be neither individualistic nor holistic within the context of social constructs. The meso-scale frames social constructs within a broad spectrum to challenge common frameworks which operate within either a micro or macro scale (Delanda, 2016, p. 124). Social constructs that operate within the meso-scale are defined as a multitude of nested assemblages containing parts that plug in and out of a collective and exhibit forms of emergent behaviour and interaction. The essence of an assemblage is derived from the notion that "a whole is greater than the sum of its parts" (Aristotle), a by-product of interacting parts which create emergent properties as a collective that cannot be reduced to any one individual. Delanda (2016) states that emergence cannot occur without interaction and subsequently disappears when interaction ceases to exist (p. 125). Defining a social construct as an assemblage therefore requires two primary conditions to be met. First, participants must interact to create the inherent emergent properties of their specific social construct, and secondly, each participant must be free to plug in and out of different assemblages, big or small, to allow the meso-scale to be utilised as a parameter through which agent-based modelling can simulate social constructs ranging from small social circles to large organisations and businesses (Delanda, 2016, p. 124).

An assemblage is defined by Delanda (2016) as a whole that is irreducible and decomposable within the context of social constructs (p. 124). These two properties stem from emergence through interaction and a relationship between parts of an assemblage through exteriority.

Two common definitions for social constructs, reductionism and holism, directly oppose Delanda's definition of assemblages within his modified theory. Both reductionism and holism play a role in how the discipline of architecture approaches social constructs, however cannot be used when developing a social framework in which Parametricism 2.0 can operate within. Delanda (2016) elaborates that reductionism ultimately reduces social constructs to an "individual, their decisions and experiences" (p. 124), subsequently neglecting constructs larger than the individual. The case against reductionism is emergence, interaction between many individuals within an assemblage, a state of collective behaviour and interaction that is irreducible to any one individual. In response to reductionism, holism defines social constructs as "seamless totalities" (Delanda, 2016, p. 124) that determine the identity of a whole and parts through interacting relations (relations of interiority). This definition operates at a macro-scale and fails to "respect the relative autonomy of what is related" (Delanda, 2016, p. 124), preventing decomposition of a social construct to understand its interacting parts because the construct is defined by its whole. Social constructs that operate at a macro-scale do not allow smaller wholes to assemble into larger constructs or allow wholes to decompose into smaller wholes. The ability for an assemblage to be recursive, to be both irreducible and decomposable, allows the framework to operate at many different social scales, defined as the meso-scale (Delanda, 2016, p. 124).

These two properties can be parametrised through agent-based modelling by controlling values associated with (de)territorialisation and (de)coding. Territorialisation determines "how rigid or flexible a territory's boundaries are and how homogenous or heterogeneous its components are." Coding determines the degree to which "the identity of an assemblage is constituted and maintained by language" (Delanda, 2016, p. 126). These two parameters are binary and should be understood as control knobs that can be turned either left or right to adjust values between each binary. Combined, these two parameters control variation within an assemblage and change how parts interact, affecting their respective emergent behaviour.

Figure 0.4: Florenza - Francesco di Lorenzo Rosselli.
Boundary between two territories in Florence, Italy c1471 - 82.

Parametric Notations.

Parametricism 2.0 can use assemblage theory to explore social functionality using parametric notation to iterate and refine social constructs specific to a context and optimise how environments can communicate social functionality through spatial legibility. Parameter-based design is a modern tool which creates rule-based geometries and forms, however Mario Carpo (2016) argues that "parametric notations are part of an enduring architectural lineage that has its roots in the theses of classical antiquity and the Middle Ages, previous to print, when the only means of disseminating the proportions and combining of elements was to describe them" (p. 25) through scripted, hand-written parameters. As a modern tool, parametric-design is an offspring to handwritten parametric notation which created rule-based designs within older styles of architecture. The history of parametric notation demonstrates how rule-based notation can be used to define design methodologies that create both general and specific results.

Carpo (2016) describes parametric design using Gilles Deleuze intrigue towards the "generality of parametric notation," stating that it is a form of general script that can "define a whole set of objects but none in particular," or in Deleuze's words an objectile (p. 26). Deleuze (1988) settles on this description for parametric notation by exemplifying how mathematical functions can use general scripts to define all parabolas generically through open variable scripts and one parabola in particular using specific variables ("The Fold."). Bernard Cache, Deleuze's student at the time proposed that "parametric notation is therefore best suited to the logic of computer-based design and fabrication," both using rule-based, logical operations (Carpo, 2016, p. 26).

As a general script within digital design, parametric notation has the capacity to produce vastly different outcomes through "specific variability" (Carpo, 2016, p. 27) Carpo (2016) exemplifies this capacity by examining rule sets written by both Vitruvius (1st century AD) and Leon Battista Alberti (1404 – 72) who "wrote manuscript treatises," verbally explaining how to build stylised architectural columns by "spelling out verbal rules on the proportions and stacking of parts" (p. 28). The verbal rules outlined by Vitruvius were particularly sophisticated due to the format of procedures which occurred, a "sequence of if-then clauses" (Carpo, 2016, p. 28) similar to what we call procedural algorithms today. Carpo (2016) highlights an example of a procedure that states "if the height of a column were to be between A and B, the modular proportions of the architrave should then by X; if comprised between A and C, the modular proportions of the architrave should then by Y, etc" (p. 28).

Relational Urban Models.

The foundations of agent-based modelling are embedded within the lineage of parametric notation, having the ability to define all assemblages generally and one assemblage exactly through specific variability. This is emphasised by Frazer within his contribution to Parametricism 2.0 and is put into practice by Enriqueta Llabres and Eduardo Rico through their joint, multidisciplinary practice Relational Urbanism. Three projects are discussed within their article, "Relational Urban Models" (Llabres and Rico, 2016) which exemplify the potential of parametric notation within urban design, developed through specificity of values that are derived from 'participatory urban models that translate data into parameters, bringing to the fore the influences of the shared relational values" of a context specific community within each project (p. 84).

Llabres and Rico (2016) describe parameters as bounds which "define a particular system from which a quantity is selected according to specific circumstances" whereas values are described as something which holds "importance or worth" for something or someone (p. 84). A parameter is relative to a system and therefore generic, whereas values are relative to an individual and therefore specific to a context. Llabres and Rico (2016) state that turning parameters into values is the "most critical issue at stake in urban parametric models" (p. 84) and recommends participatory data as a means to collect 'value' from a context to inform "relational urban models." Values, used as input parameters within methodologies such as agent-based modelling, are said to hold a tacit dimension. Llabres and Rico (2016) describe this quality as "knowledge that can be conceptualized and transmitted before it can be explicitly rationalized" (p. 85). The specific variability of value and its tacit dimension, the experience and memories of an individual imbedded within their environment, allows Llabres and Rico to respond specifically through their relation urban models by collecting knowledge and using it as parameters within their established methodology. The tacit nature of context-specific values bring to light specific design issues that cannot be determined rationally from an objective standpoint of a designer not familiar with the respective social or economic condition of a context. Understanding and gathering value as potential parameters is therefore required if an urban design is to be responsive to a particular context.

Figure 0.5: Urban Regeneration - Relational Urbanism.
Generating options for urban rejuvenation within Santos, Sao Paulo using tactic, local input.

Methodology Analysis.

This section introduces various methodologies developed by designers who've explored agent-based modelling within their respective design projects. Each project unpacks various attributes of agent-based modelling that will inform the development of an agent-based methodology within the design investigation of this research. Agent behaviour, environmental artefacts and swarm intelligence will be analysed within each methodology to unpack different approaches designers have taken to achieve their respective design agenda.

Flocks, Herd and Schools: A Distributed Behavioural Model.

Craig Reynolds is a software engineer based in Los Angeles, California who established three principle parameters that mimic naturally occurring swarms such as birds flocking and schools of fish through digital simulation. Reynold's (1987) behavioural model for naturally occurring swarms was developed using a flocking simulator titled "Boids" which utilised collision avoidance, velocity matching and flock centring as the three principle parameters for recreating natural swarms. This project was presented within an article titled "Flocking, Herds and Schools: A Distributed Behavioural Model" that explained how he established agency within particles in a digital environment. The flocking simulator was created as an alternative to individually scripting the pathing of birds by developing a rule based particle system that used the three principle

Figure 0.6: Birds Flocking - Robert Wolstenholme.

parameters, creating an emergent, life model tool that agent-based modelling later adopted (Reynolds, 1987). The three principle parameters Reynolds' developed allows each particle (agent) to behave cohesively within a de-centralised swarm, comparable to how individual birds of a flock or fish within a school behave. The focus of the tool was to develop the behaviour of individual particles to encourage interaction whilst maintaining autonomy. Each behaviour was coded to be intelligent in detecting neighbouring agents and responding to them through pre-established actions. Collision avoidance allowed individual agents to avoid collision with nearby flock mates, velocity matching attempted to match an individual agent's velocity to its nearby flock mates and flock centring grouped individual agents together if within proximity (Reynolds, 1987).

Reynolds concludes his paper by identifying various compound behaviours that can be developed using the three principle parameters to produce more complex interactions that simulate intricate natural systems like interaction between humans. Complex behaviours offer more potential actions for an agent when met with various conditions and subsequently produce more intricate swarms of interaction (Reynolds, 1987). The three principle parameters and flocking methodology developed by Reynolds forms the foundation of the agent-based methodology being developed within this design research as guidelines towards establishing qualitative behaviour within particle systems to simulate the various demographics of New Delhi's urban population.

Figure 0.7: Boids Simulation - Craig Reynolds, 1987.

Main Museum (Art)

De-centralised organisations such as swarms offer the ability to test simple interactions between agents and environment to understand the effect of small changes in behaviour and environment to the collective intelligence. The collective intelligence of a de-centralised organisation is often unpredictable and irregular, allowing insight into emergent behaviour that designers would otherwise not be able to consider within architectural design.

Tom Wiscombe utilises the emergent properties of swarm intelligence to test the integration of his Main Museum design project within its context in Los Angeles, California. Wiscombe's methodology is relevant to this design research as it offers an example of how a designer can use an agent-based methodology to inform architectural design specifically. Wiscombe (2014) has tested changes in swarm intelligence by introducing elements from site into the simulation process to understand how his design could best integrate with existing circulation pathways and the local subway gate. The particle system within his methodology found optimal routes that connected his design into surrounding elements and found new pathways that could optimise how pedestrian traffic could directly access the rooftop design without diminishing the historical building on which it sat on. Plugging in urban elements and testing agents within their environment allowed Wiscombe to understand the effect of his design on the existing processes around site and ultimately allowed the design to contribute towards preserving existing relationships urban relationships. Wiscombe's agent-based methodology offers a starting point from which a particle system can be developed to test environmental artefacts and agents, iteratively refined to integrate new urban design into an existing context.

Figure 0.8: Main Museum, Los Angeles. Tom Wiscombe Architecture, 2014 - 2017.

Melbourne Docklands.

Kokkugia is an experimental research collaborative led by Roland Snooks and Robert Stuart-Smith who explore generative design methodologies and in particular, the use of agent-based modelling at various scales of fabrication and architectural application. The Swarm Urbanism project by Kokkugia looks at Melbourne's Docklands in Australia to speculate an alternative, agent-based approach towards rethinking the docks function if redesigned. Snooks and Smith (2009) comment on the use of swarm intelligence within urban design as a means to "shift from master plan to master algorithm as an urban design tool" (para. 1) that has the ability to self-organise. The ability to change through self-organisation allows a potential urban design operating through swarm logic to respond to a consistently changing political, economic, and social climate of a social context (Snooks and Smith, 2009). Kokkugia have used agent-based modelling within their Melbourne Docklands project by establishing two categories of agents that operate independently, the first set of agents assigned the task of self-organising program through stigmergic growth and the second, assigned the task of organising infrastructure and circulatory networks through minimal paths. The result of Kokkugia's experiments show a visually emergent urban design solution that changes and stabilises over time and responds to set parameters and artefacts on site. Giving agency to urban elements allows their methodology to be applied at various scales of urban development and will inform the development of an agent-based methodology within this design research. The objectives that align with the proposed agent-based methodology and Kokkugia's Melbourne Docklands project are an emphasis on utilising the emergent properties of swarm intelligence to create urban design solutions that respond to the socio-economic context of a city through established agencies.

Figure 0.9: Melbourne Docklands, Kokkugia, 2009.

Preliminary Design.

The preliminary design chapter will aim to explore issues derived from the research aims and objectives, as well as context analysis and literature review. The primary question being explored within this chapter is whether a speculative bottom-up approach to urban design can foster inclusivity through diverse social and economic interaction, created and tested by simulating the behavioural tendencies and interaction of a context specific demographic. The aim of the investigation is to develop an agent based methodology that simulates demographic behaviour and interaction to inform design of inclusive urban environments using the emergent properties of agent-based modelling. The methodology will be developed by assigning agency to particles and objects through preliminary design experiments that will later inform abstract representations of context-specific urban elements during developed design.

Simulations will output a pre-geometry state of information that will require a series of design experiments which explore populating infrastructure and typology into the output to understand how bottom-up urban environments might organise urban elements. This design issue will be explored by populating geometry into a simulation output to understand how agents might organise urban elements within an environment through behaviour and interaction.

Outlined below is a diagram that shows the structure of design experiments that this chapter follows as it develops upon iterations to reach resolution on design issues pertaining to each series of explorations. The design issues being explored will aim to address either the research question, the aims or objective of the research, or a site-specific and/or literature and theory specific design issue outlined within the previous chapters.

Figure 1.1: Preliminary Principles.
Utilising preliminary design experiments explored within this chapter.

Emergence Through Particles.

Design experimentation begins by exploring the properties of particle simulations within Autodesk Maya, a software developed to handle various types of physics based simulations. Maya allows simulations to operate along a timeline, allowing experiments to evolve and grow within an assigned interval of time. The aim of these initial experiments are to understand the emergent properties of particle simulation, interpreted through the lens of "spatial potential" and interaction potential between various agents (particles).

Findings:

The following experiments show a strong spatial legibility and interaction potential that justifies the use of a particle system as a basis for creating an agent-based methodology that addresses various design issues outlined within this research. The emergent properties of a particle system allows exploration of behaviour driven simulation as a means to observe interaction through congregation and areas of increased collision within the collective interaction as a whole. Patrik Schumacher has suggested the use of agent-based modelling as a means to test social interaction through spatial legibility within the manifesto of Parametricism 2.0. The aim of this design research and moment in which these design experiments diverge from the manifesto is the intention of creating environments through interaction of agents and their environment, rather than using agent interaction to test a pre-designed architectural model. In essence, this research aims to create social functionality by organising spatial and urban elements around a model of interaction that abstractly represents the behaviour of occupants.

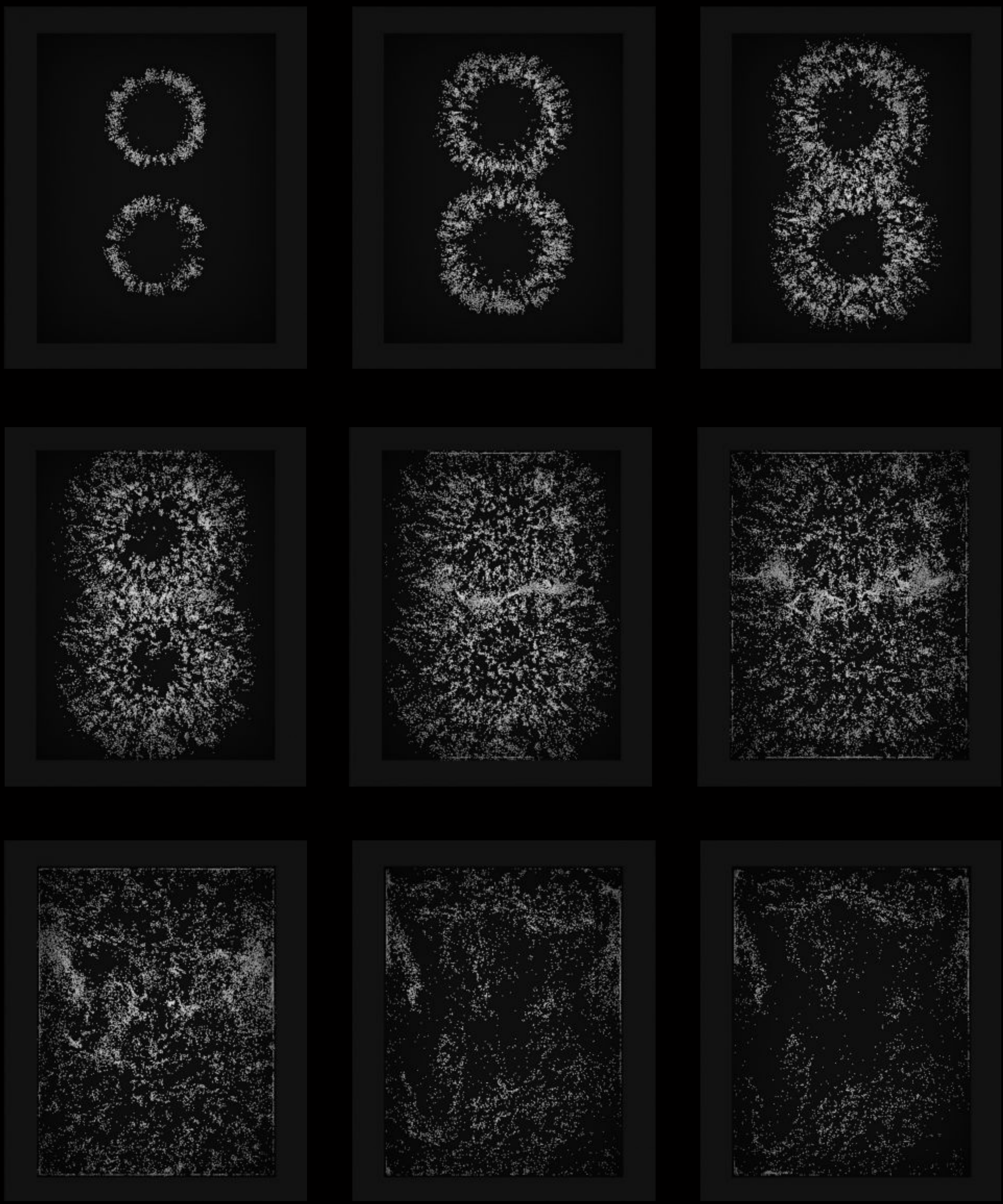


Figure 1.2: Bifrost particle series 1.
Exploring the emergent nature of particles.

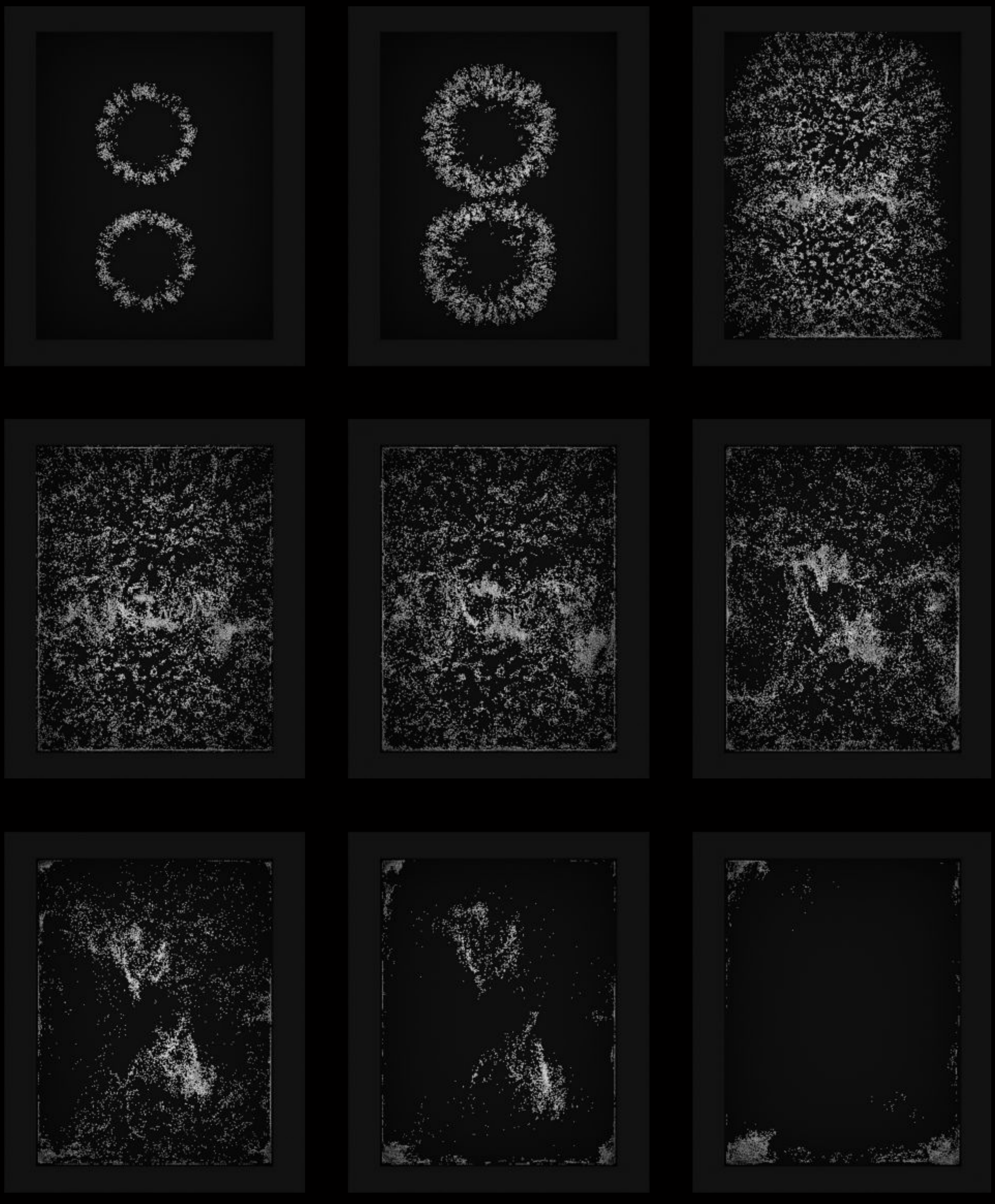


Figure 1.3: Bifrost particle series 2.

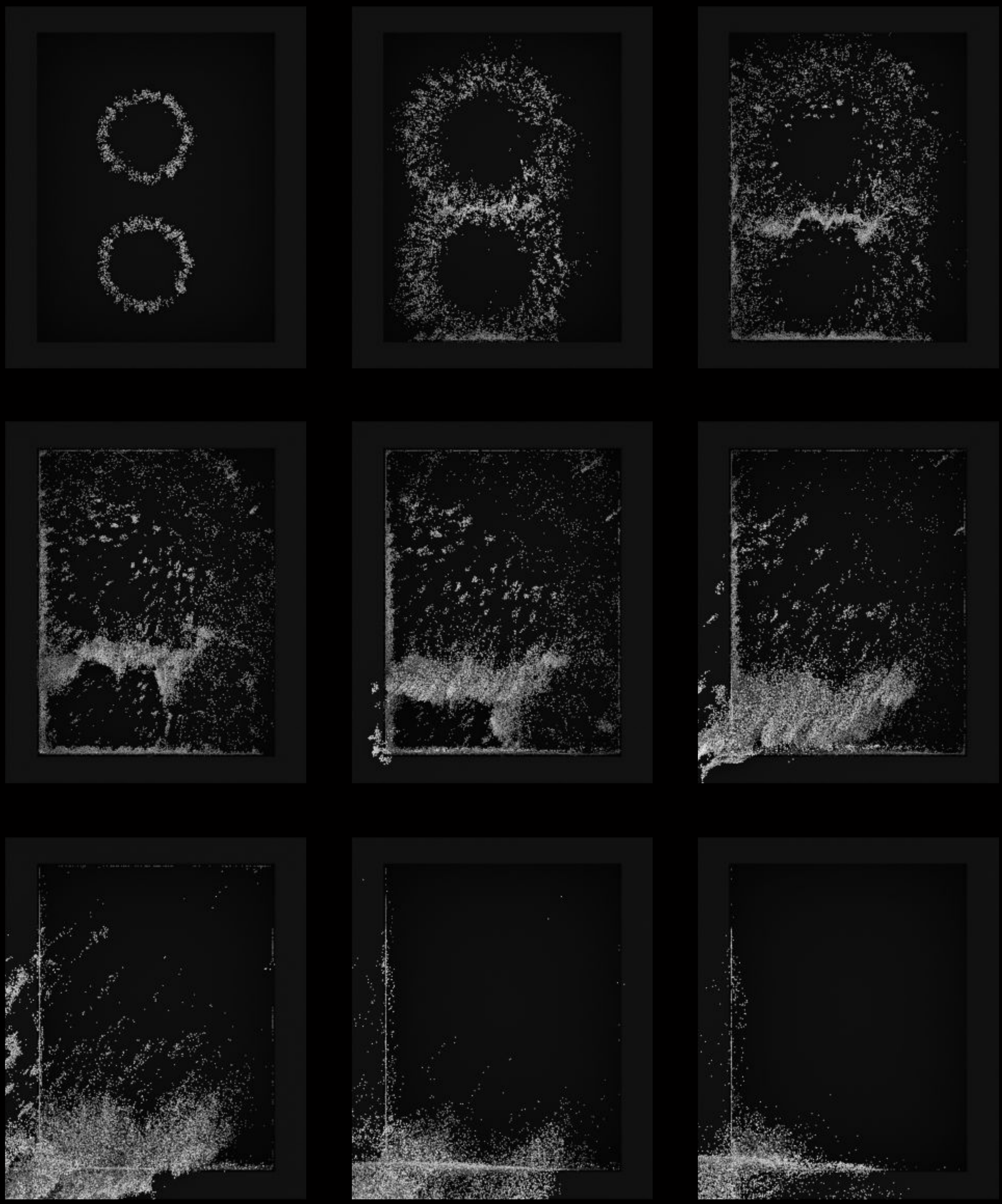


Figure 1.4: Bifrost particle series 3.

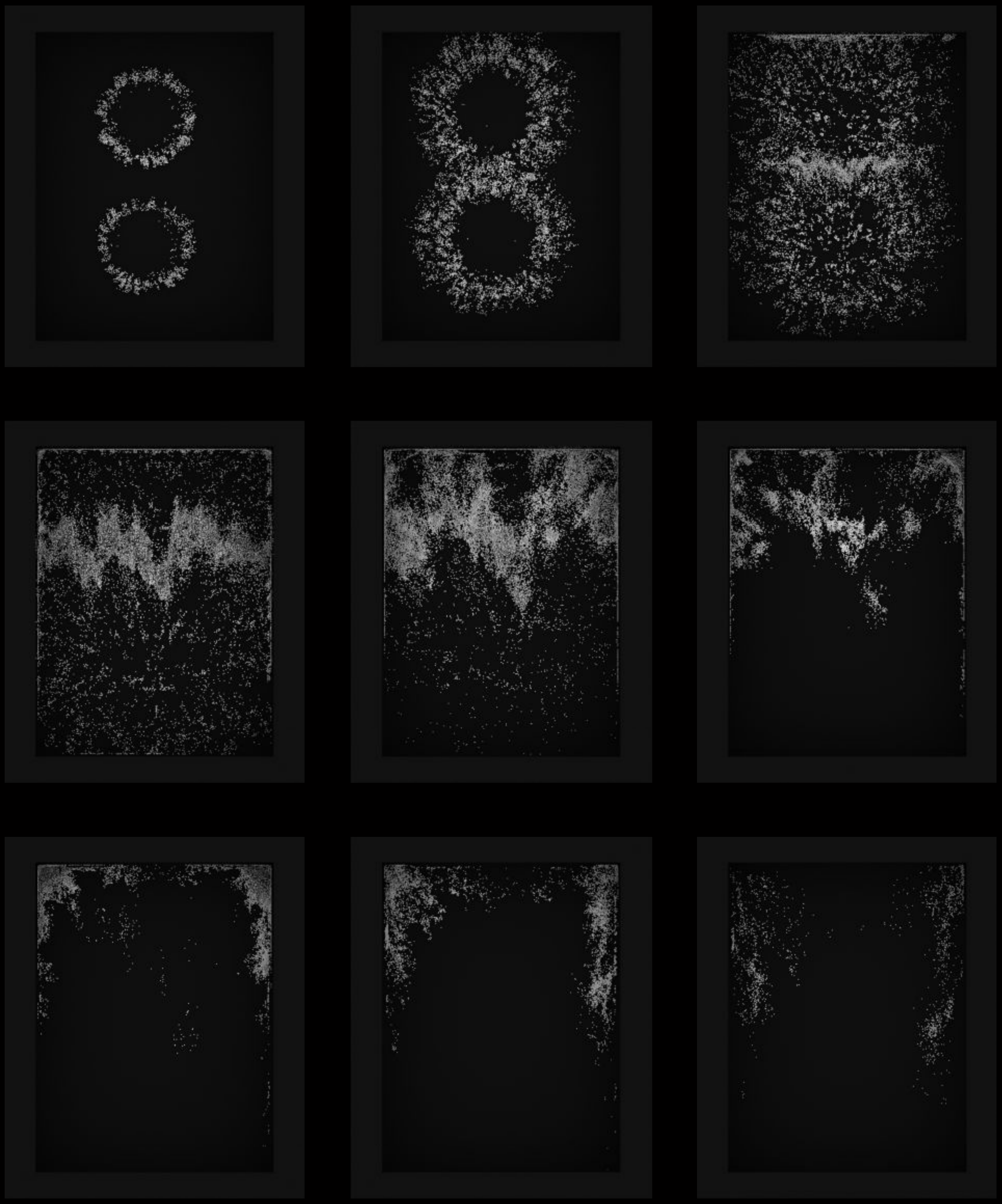


Figure 1.5: Bifrost particle series 4.

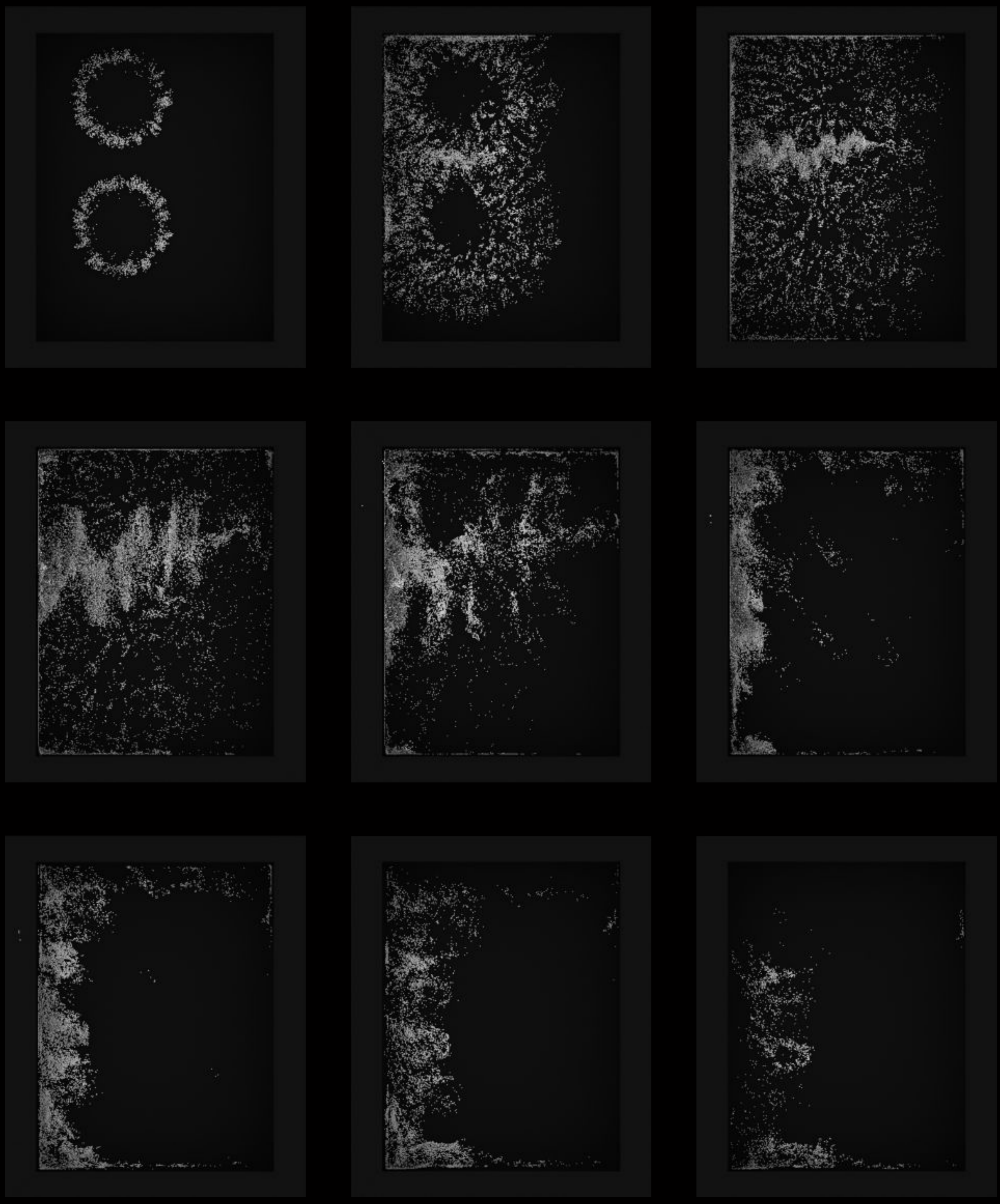


Figure 1.6: Bifrost particle series 5.

Particle Agency.

The main research objective looks at assigning agency to particles and urban elements using input parameters that address how the simulation can produce various types of interactions between agents. The following series of design experiments look at assigning agency to particles through influence of physics based solvers that have the ability to attract, repel, rotate, revolve, disrupt and homogenise agents within the particle system. These physics solvers give each particle an internal behaviour that is controlled through an assigned magnitude (value) within the simulation. The following experiments assign a variety of physics solvers to a particle system and document the simulation over time to understand the effects of each solver and their assigned magnitude.

Findings:

These design experiments show the effect of different physics solvers on a particle system and the variation each brings to the simulation. This variation is attributed to the different solver types used and their assigned magnitudes which affect how each simulation develops over time. Variation between each particle system, solver type and input parameters used becomes evident when comparing the final output of each simulation. Simply changing the magnitude of a physics solver whilst utilising the same simulation parameters also has an observable change in behaviour that should be noted. These design experiments catalogue various abstract representations of particle agencies which can be assigned to context specific simulations during developed design.

Figure 1.7: Particle Interaction.
Abstract colouration of different particles interacting.

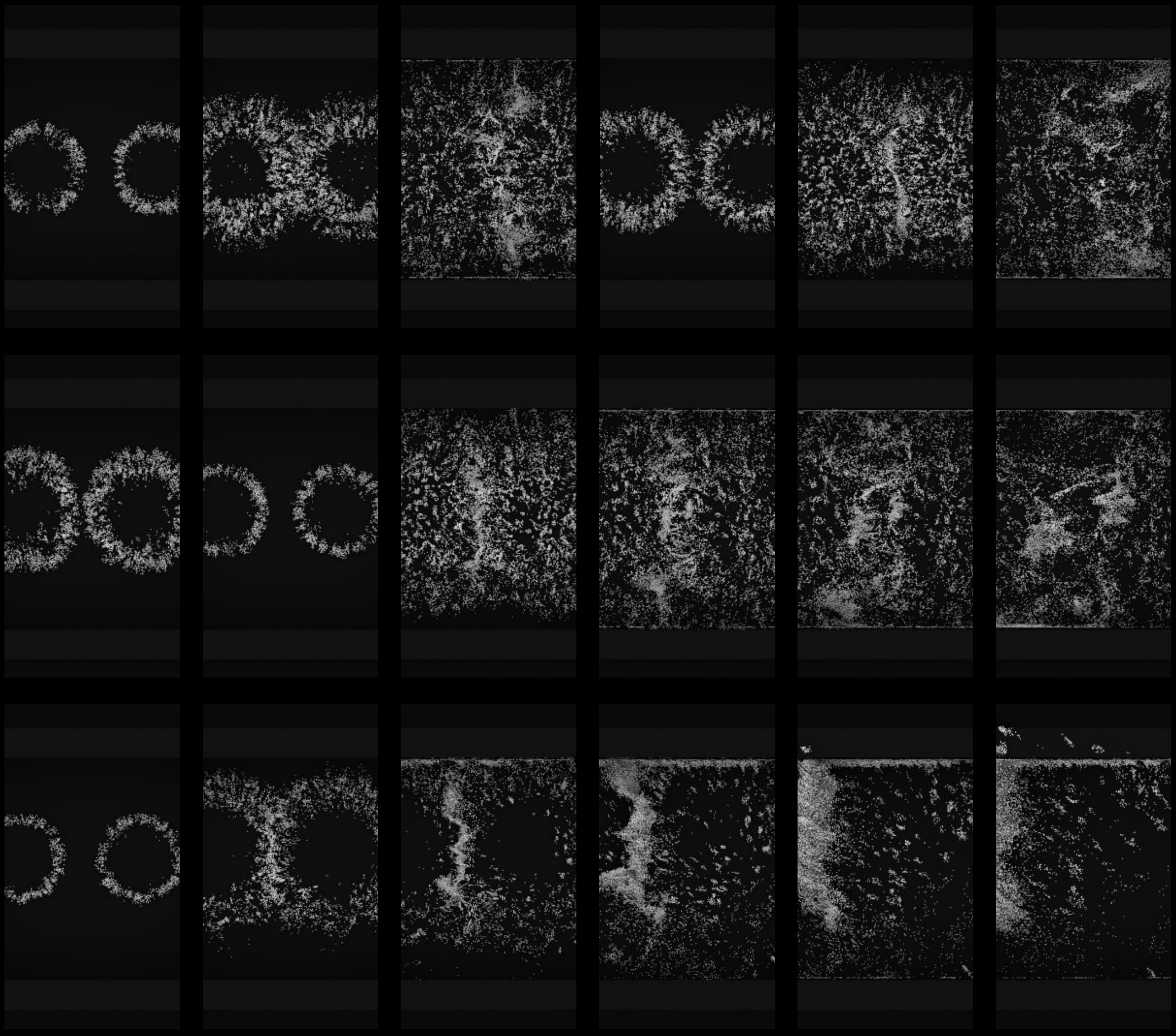


Figure 1.8: Particle Agency through Solvers - Series 1.
Exploring the effect of physics solvers as internal behaviour.

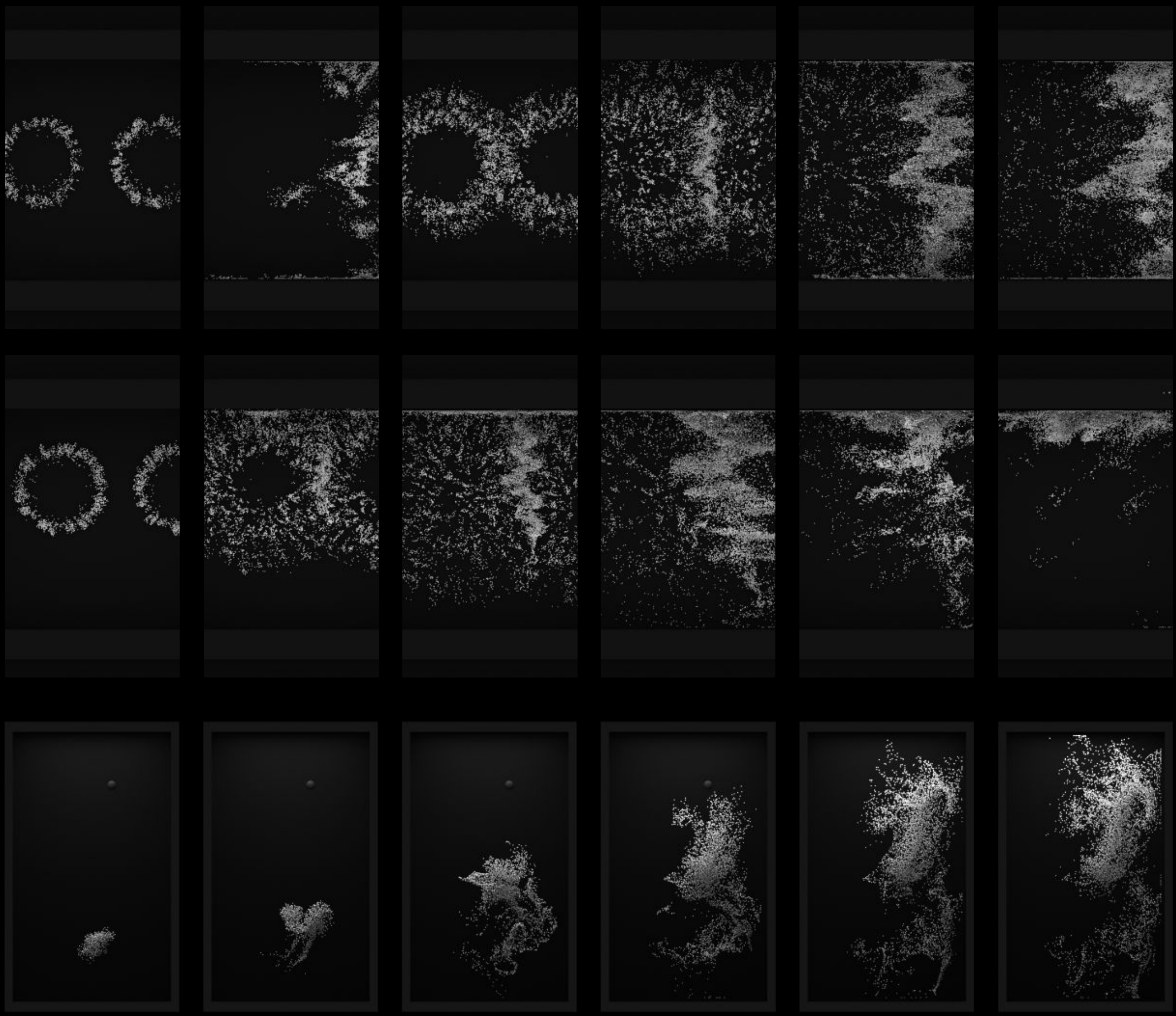


Figure 1.9: Particle Agency through Solvers - Series 2.

Figure 1.10: Particle Agency through Solvers - Series 3.

Figure 1.11: Particle Agency through Solvers - Series 4.

Environmental Influencers.

Design issues derived within the context and site analysis chapter orient the methodology towards addressing specific socioeconomic areas unique to New Delhi and their master plan leading up to 2021. The DDA (Delhi District Authority) have outlined modernisation of infrastructure, land-use zoning laws and visual character development as key commitments for New Delhi's master plan. Infrastructure and the city's visual character are two aspects of New Delhi's development that can be addressed within the scope of this design research. The following design experiments aim to test objects within simulation space that abstractly represent physical landmark elements within New Delhi's existing context. These objects are assigned agency as environmental influencers that affect the behaviour of agents (particles) through proximity and currently contribute to the visual character of New Delhi. These elements are referred to by Schumacher within the Parametricism 2.0 manifesto as artefacts within the environment and form the minimal unit of communication when translating social functionality via spatial legibility.

Findings:

Particles were programmed to change colour to distinguish agents that were affected by the influence of artefacts within proximity. These design experiments show various parameter configurations between the internal behaviour of agents and the external influence of artefacts, developed iteratively to create variation in behaviour and interaction between similar agent types. These experiments show the potential of an agent's ability to change behaviour when in proximity of an artefact. The ability to change behaviour through proximity to existing urban elements will help the developing agent-based methodology test new landmark typologies and infrastructure during developed design. Existing artefacts will inform the design of new socioeconomic hubs and infrastructure, creating a feedback loop as the designed urban ecology develops over time.

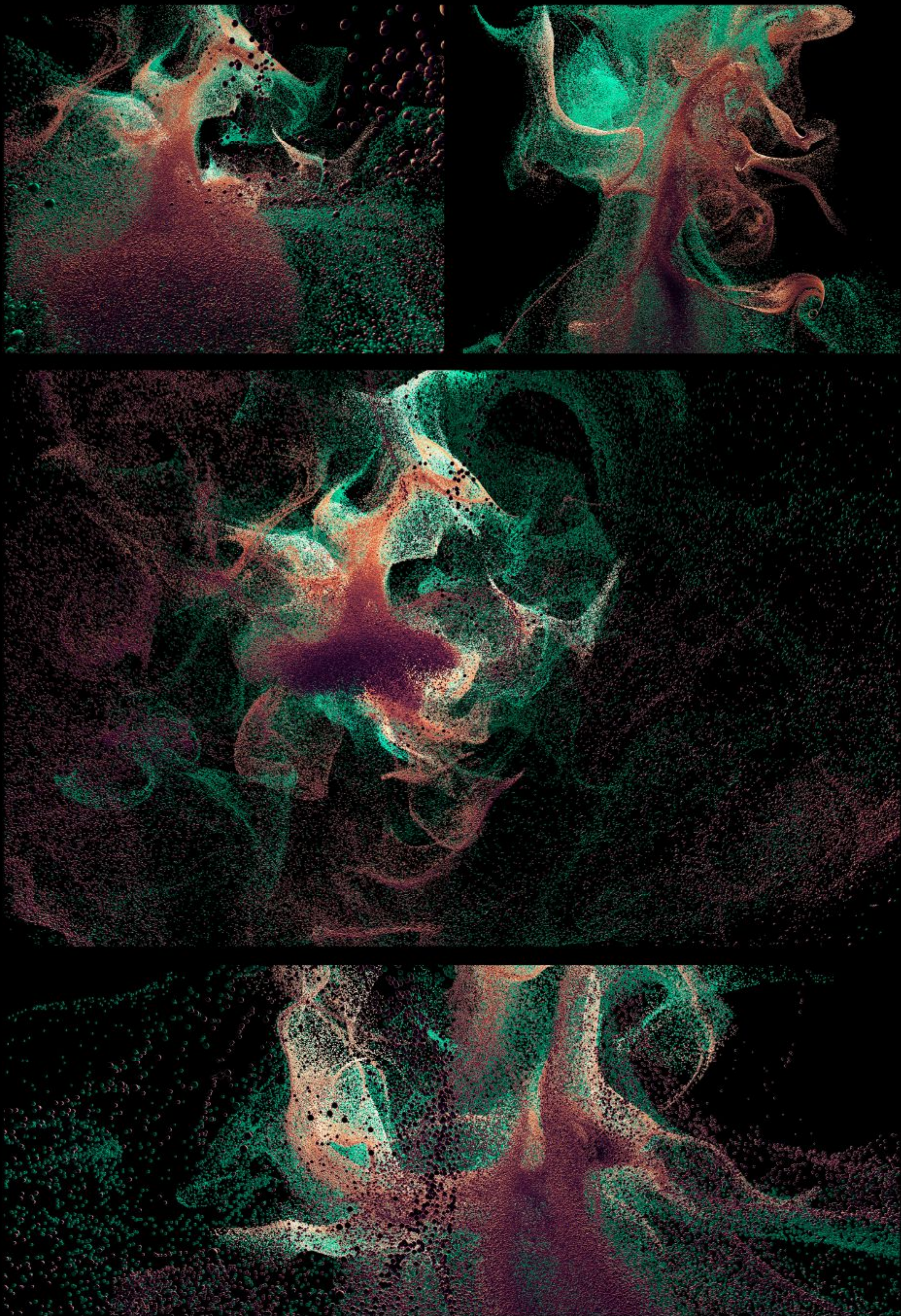


Figure 1.12: Particle Emergence.
High density interaction of particles.

Figure 1.13: Artefact Influence - Series 1.
Artefacts changing agent behaviour through collision.

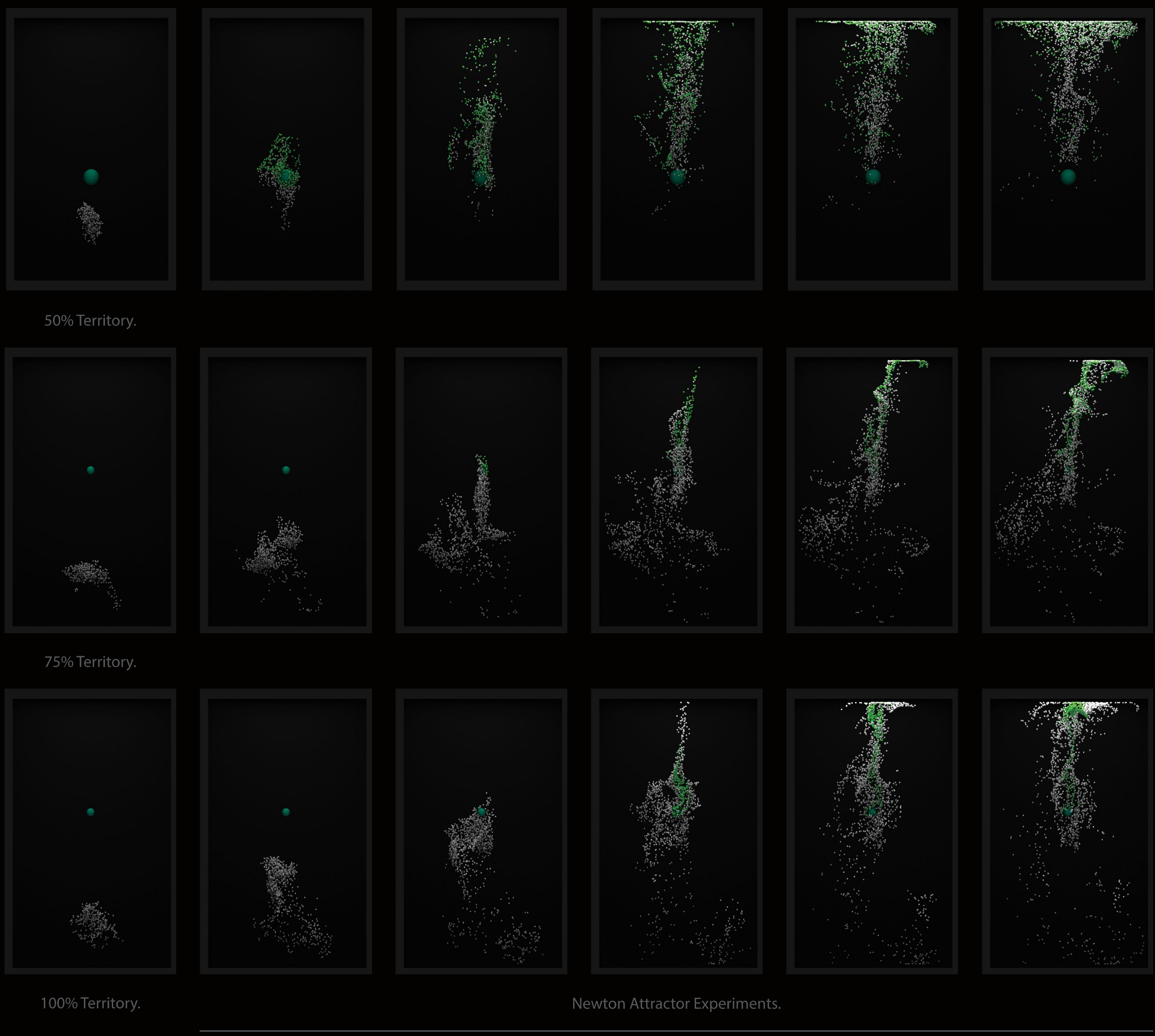


Figure 1.14: Artefact Influence - Series 2.

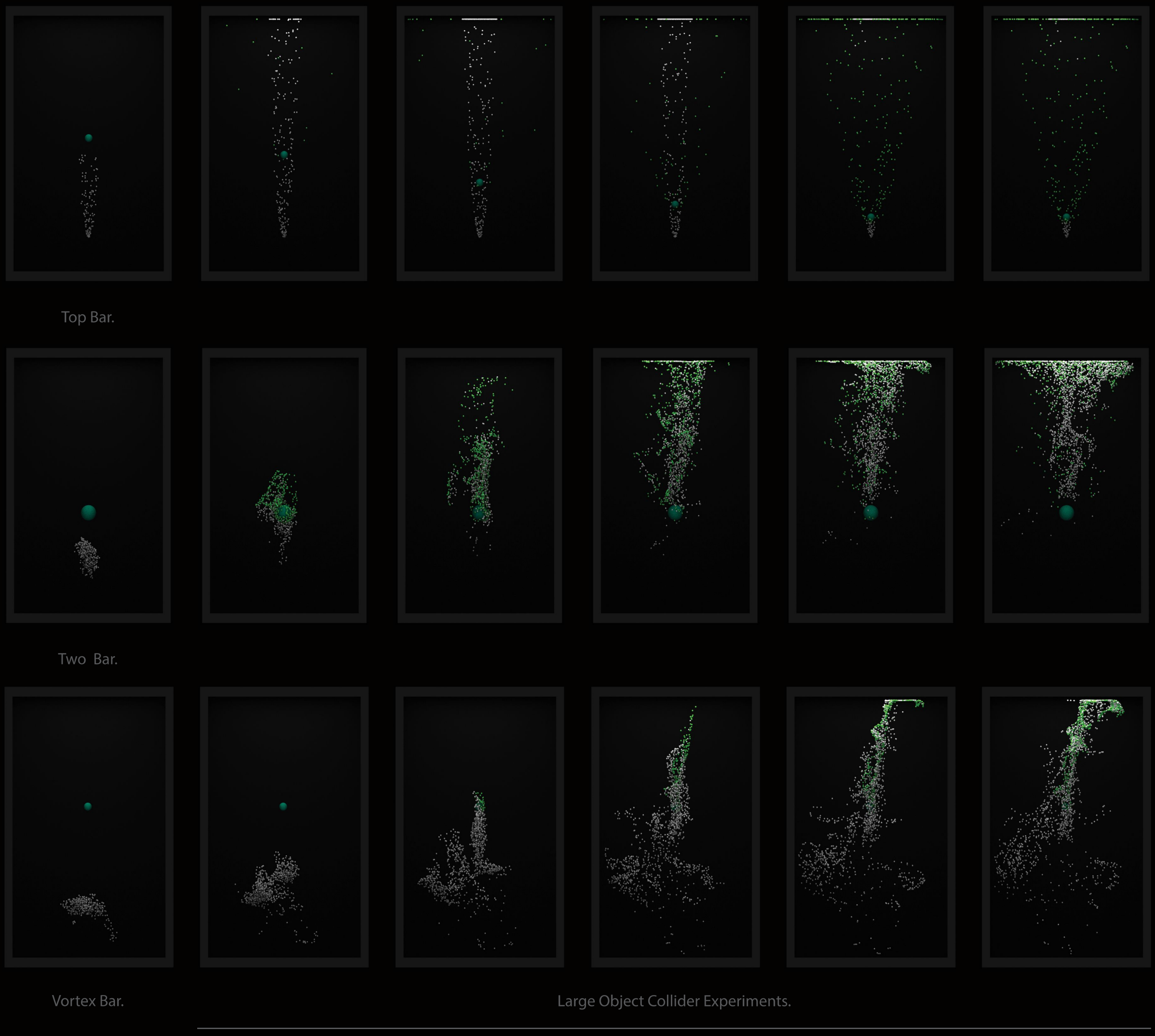


Figure 1.15: Artefact Influence - Series 3.

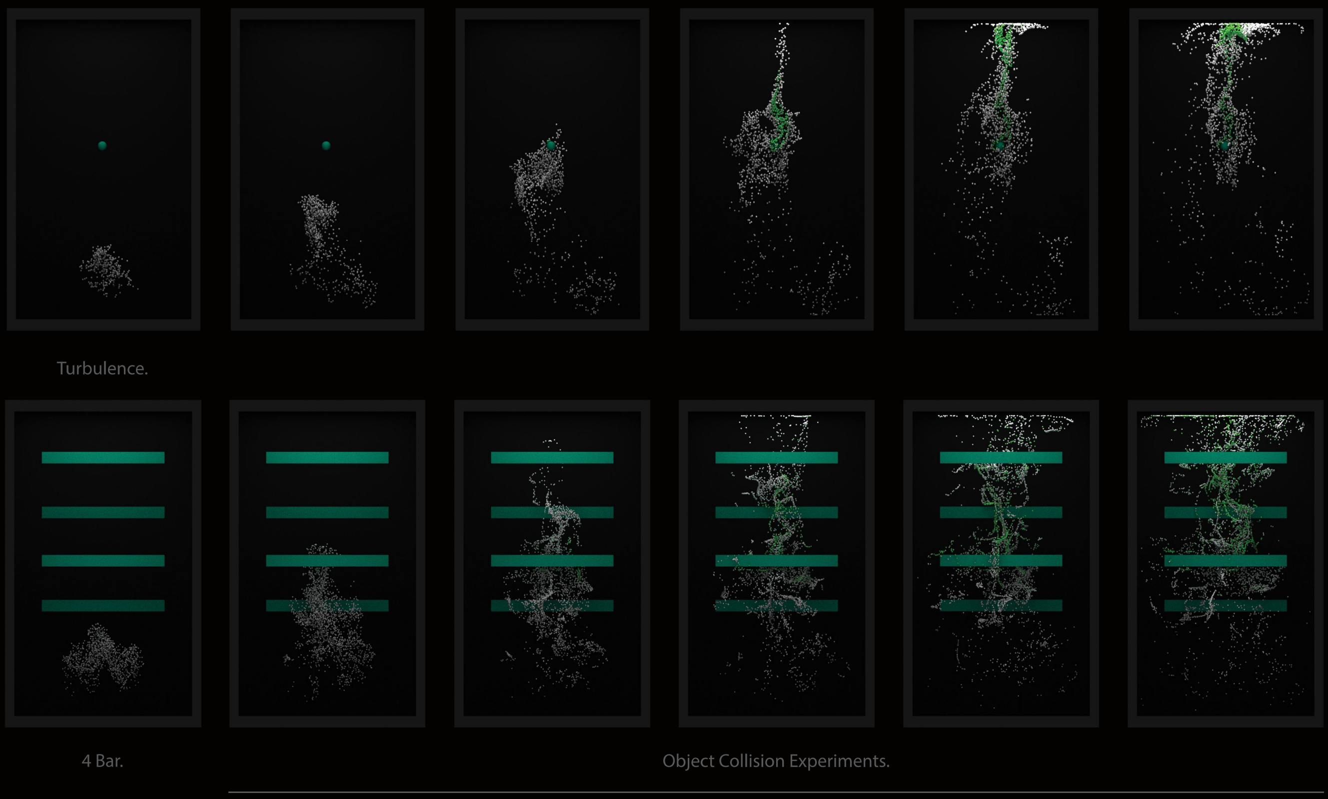


Figure 1.16: Artefact Influence - Series 4.

Mapping Agent Behaviour.

Previous design experiments have shown agent behaviour and interaction during different snapshots of a simulation, frozen within a particular moment. The following design experiments explore the notion of tracking agent trajectories using physical trails that manifest the particle's movement into physical geometry. These trails have the capacity to show changes in behaviour and moments of interaction where trails overlap and change direction. Each trail indicates the beginning and end of an agent's trajectory and can be developed further to inform early mass models, instanced typologies and other design interventions.

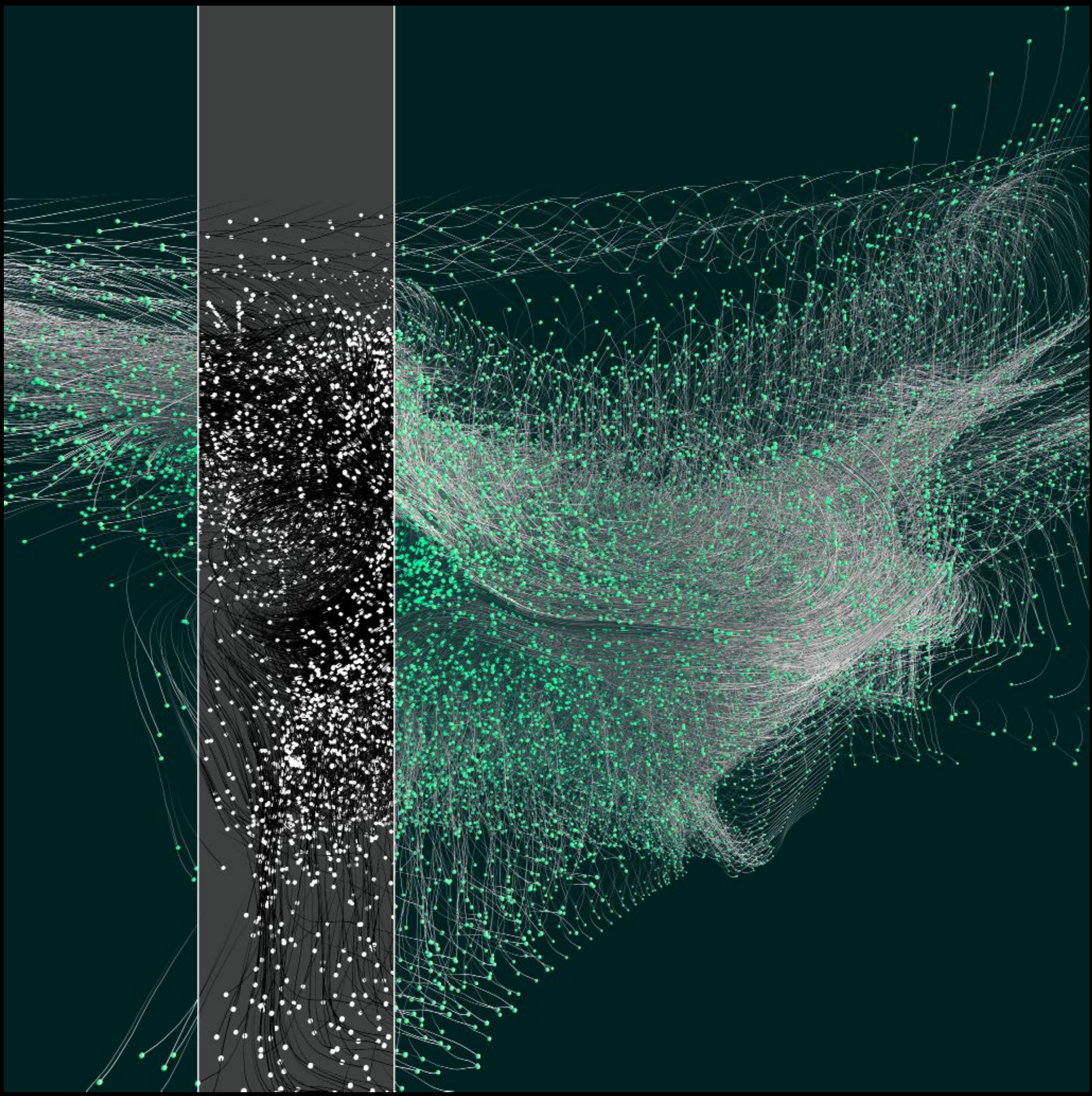


Figure 1.17: Recursive Swarm Ecology.
Merging two simulations to generate hybrids.

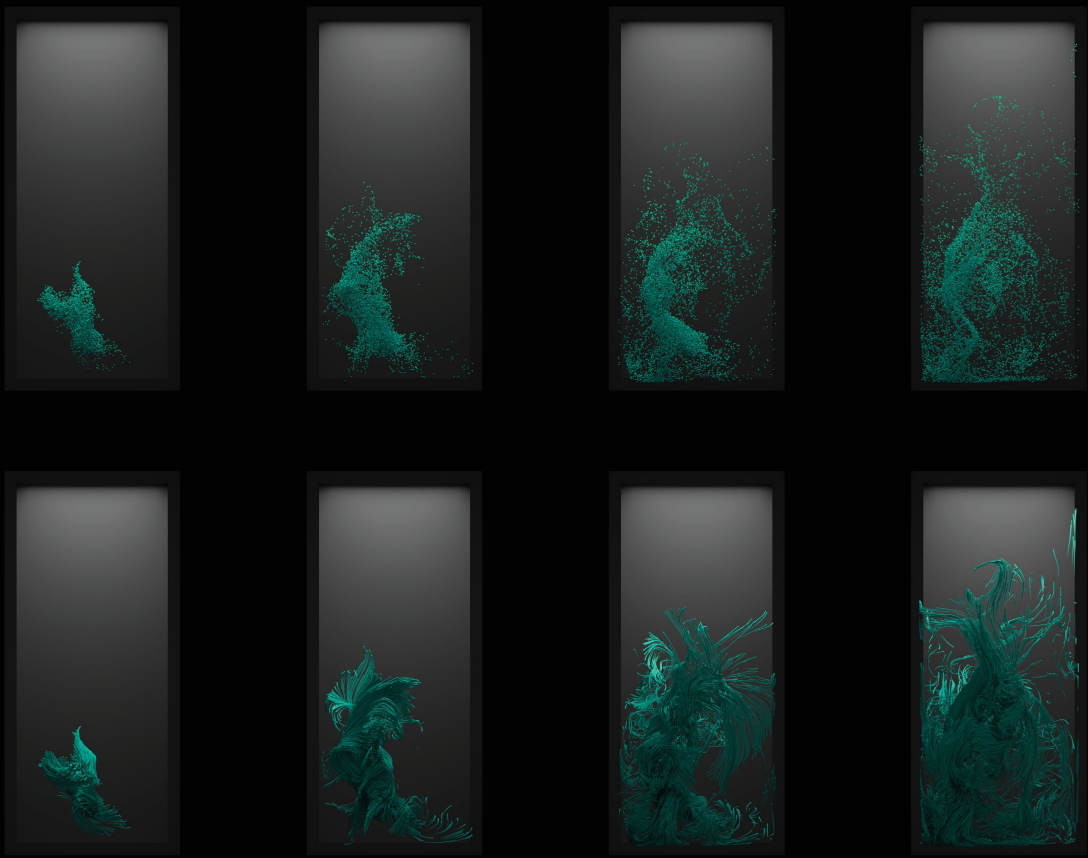


Figure 1.18: Comparing Particles to Trails - Series 1.
Exploring the differences between snapshot representation and physical timeline for particle simulations.

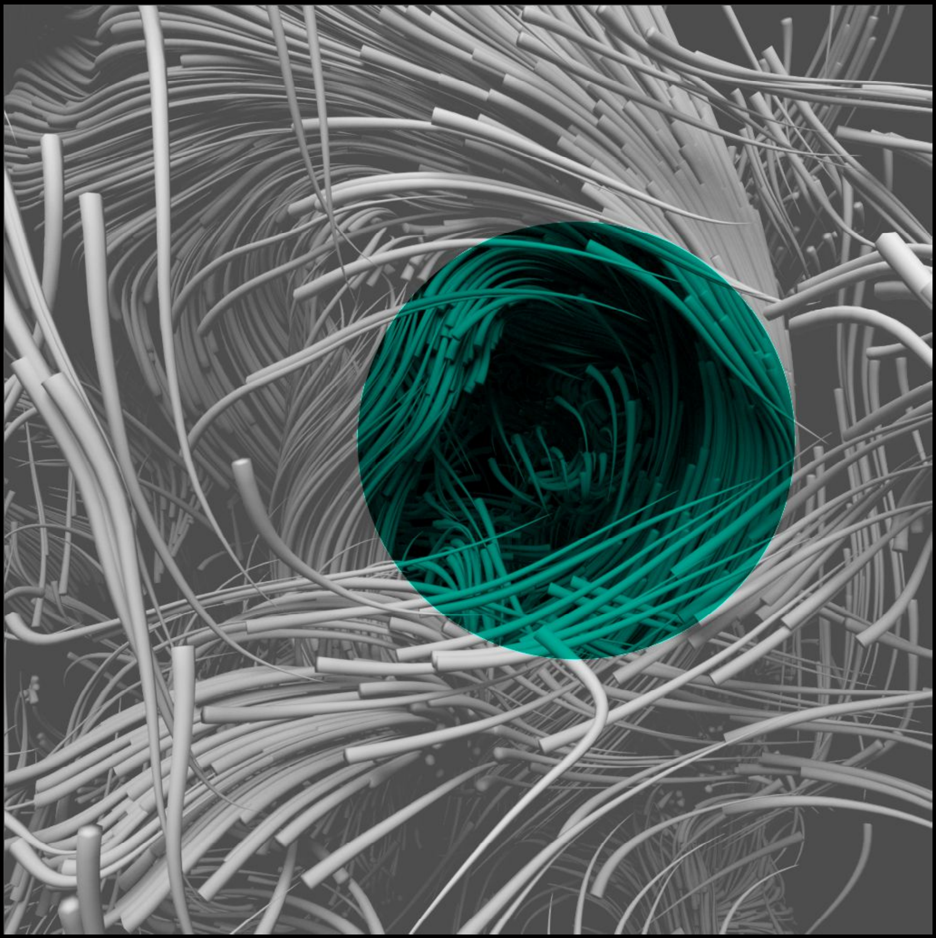


Figure 1.19: Series 1. Trail Overlap.
Overlapping trails show areas of interaction for a number of particles.

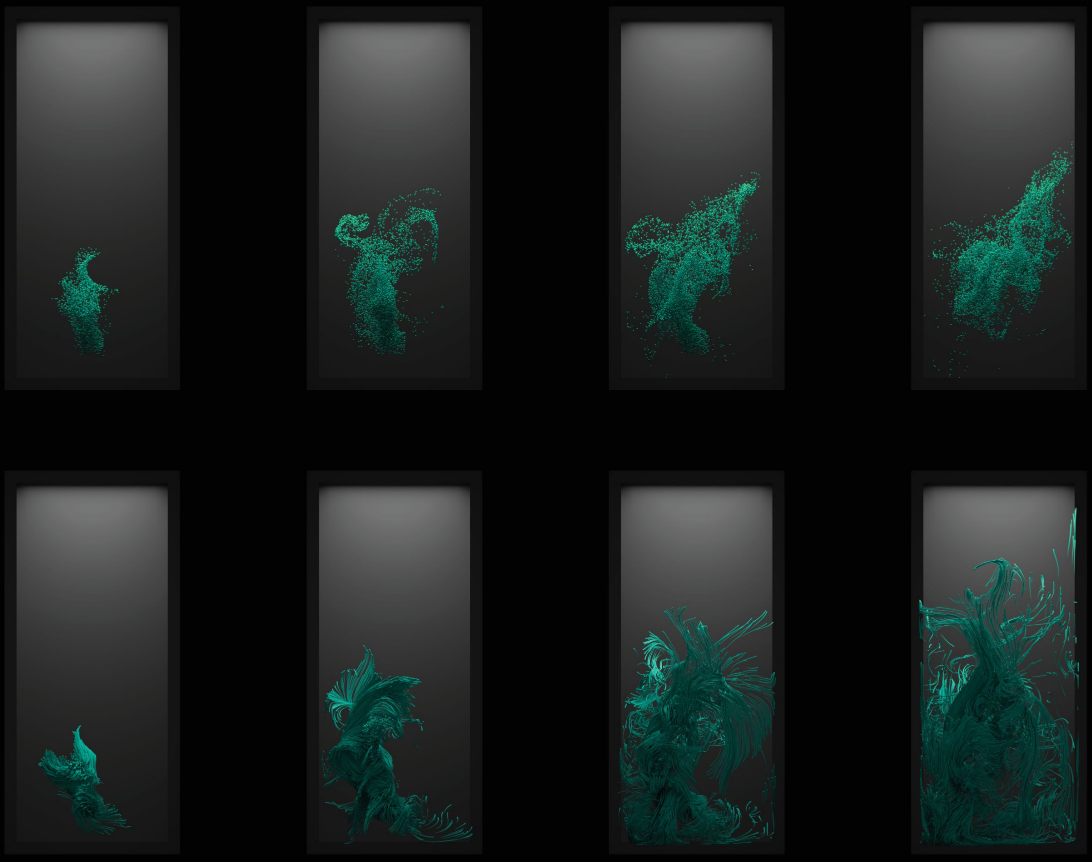


Figure 1.20: Comparing Particles to Trails - Series 2.

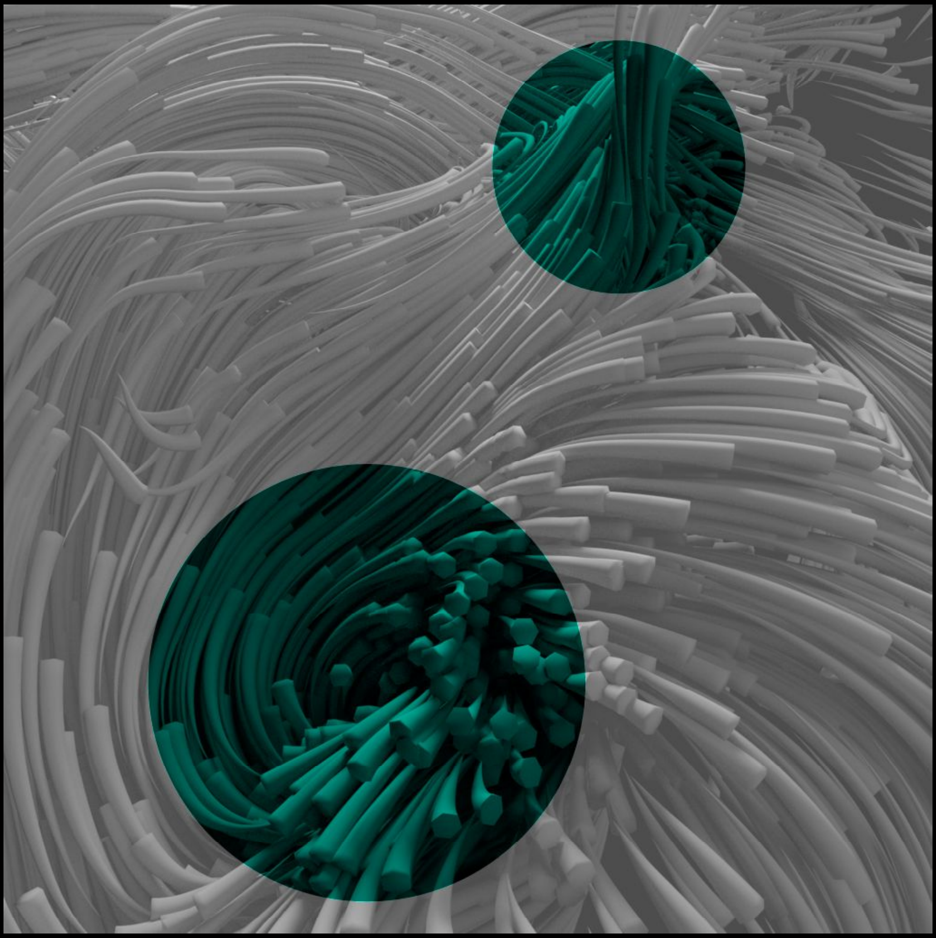


Figure 1.21: Series 2. Trail Overlap.

(De)Territorialisation.

Territorialisation is a concept discussed by Delanda as the extent to which agents can plug and unplug into different assemblages. The ability for an assemblage to bleed its territory to allow both external and internal parts to contribute to its emergent interaction is relevant to understanding how an existing urban environment can contribute to new behaviour driven, urban designs and vice versa. The following design experiments look at creating territory within a simulation space, using fluid systems that affect the extent to which an agent will remain within the defined borders of their respective territories. The ability to control the softness of a territory's border will inform how varied the interaction between different demographic types will be within developed design. De-territorialisation is therefore the primary objective of the following design experiments, allowing smaller assemblages to come together by bleeding and merging their territory borders.

Findings:

The following design experiments show how particles congregate within dense areas of fluid (territory) whilst using less dense areas to travel in between areas of congregation. Later experiments present multiple territories to test how agents react when given multiple choices. These experiments show a tendency for agents to travel to territories closest to their location and are affected by the magnitude of an urban element's agency, changing their internal behaviour. Finally these experiments show an ability for territories to grow and bleed their borders into adjacent territories, creating larger areas of inhabitation for otherwise localised agents. The notion that territories can share agents with one another allows the developing agent-based methodology to test small assemblages together to create inclusive and collective interaction between otherwise separated assemblages in New Delhi.

Figure 1.22: Particle Territory Colourisation.
Bleeding territory borders to merge different agent types.

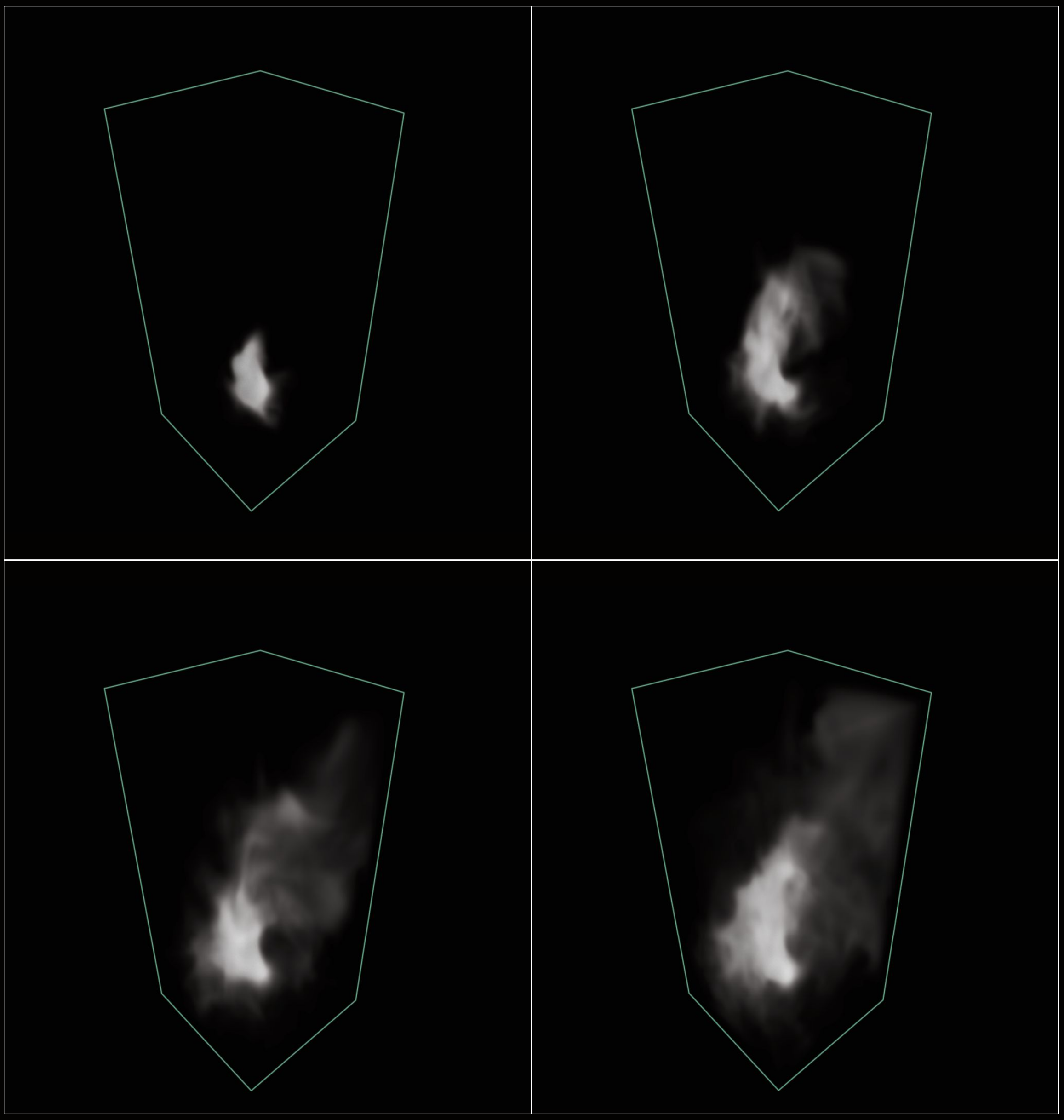


Figure 1.23: Single Territory (Fluid).
Growing a territory over time.

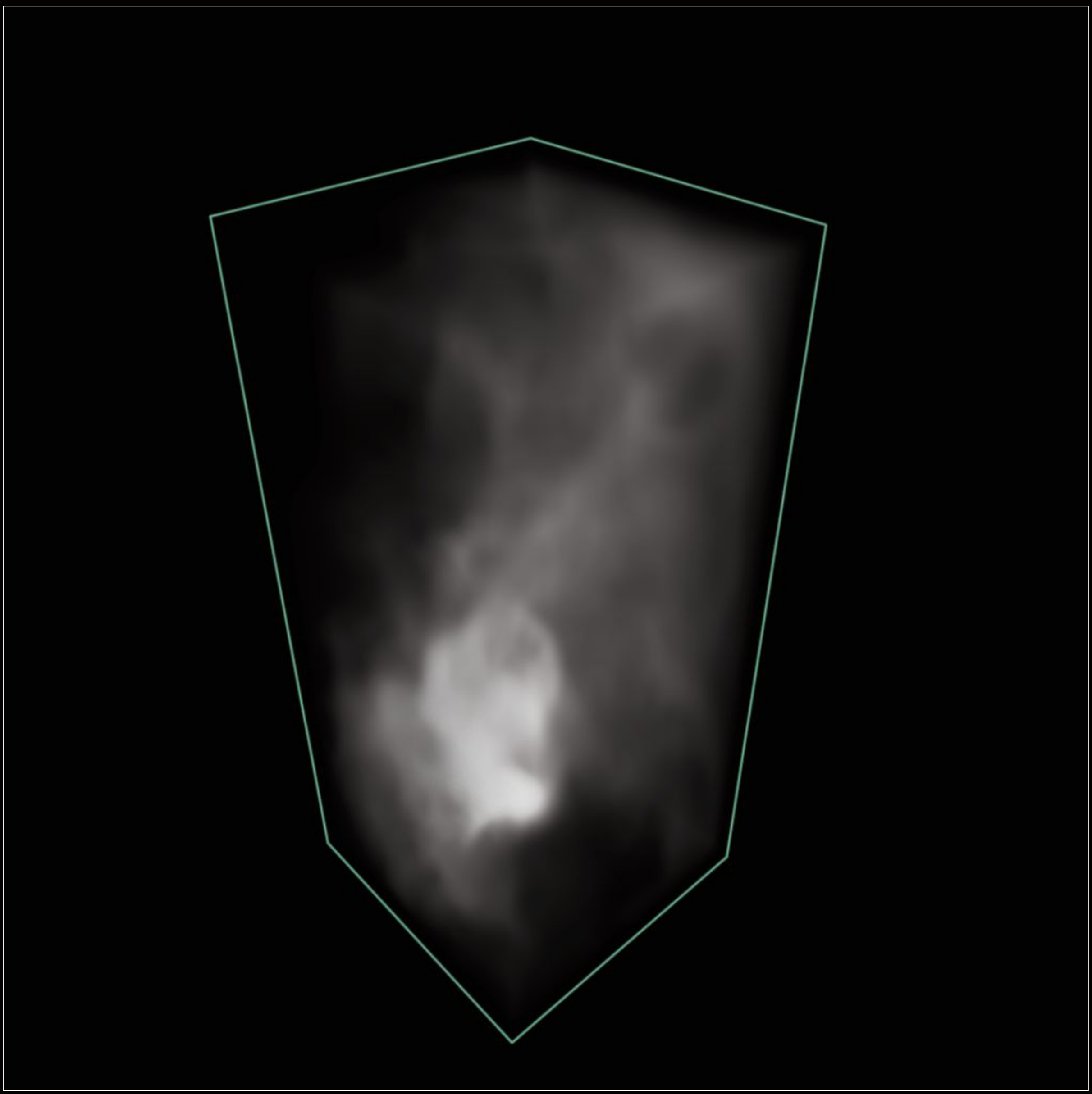


Figure 1.24: Single Territory - Full Simulation.
Final simulation state of single territory.

A single territory (represented by a single fluid type) was simulated to provide an area in which agents can exist within defined borders. This territory shows what the border condition of a defined agent type may look like without considering adjacent territories.

Figure 1.25: Single Territory - Trail Simulation.
Simulating agents within a single territory.

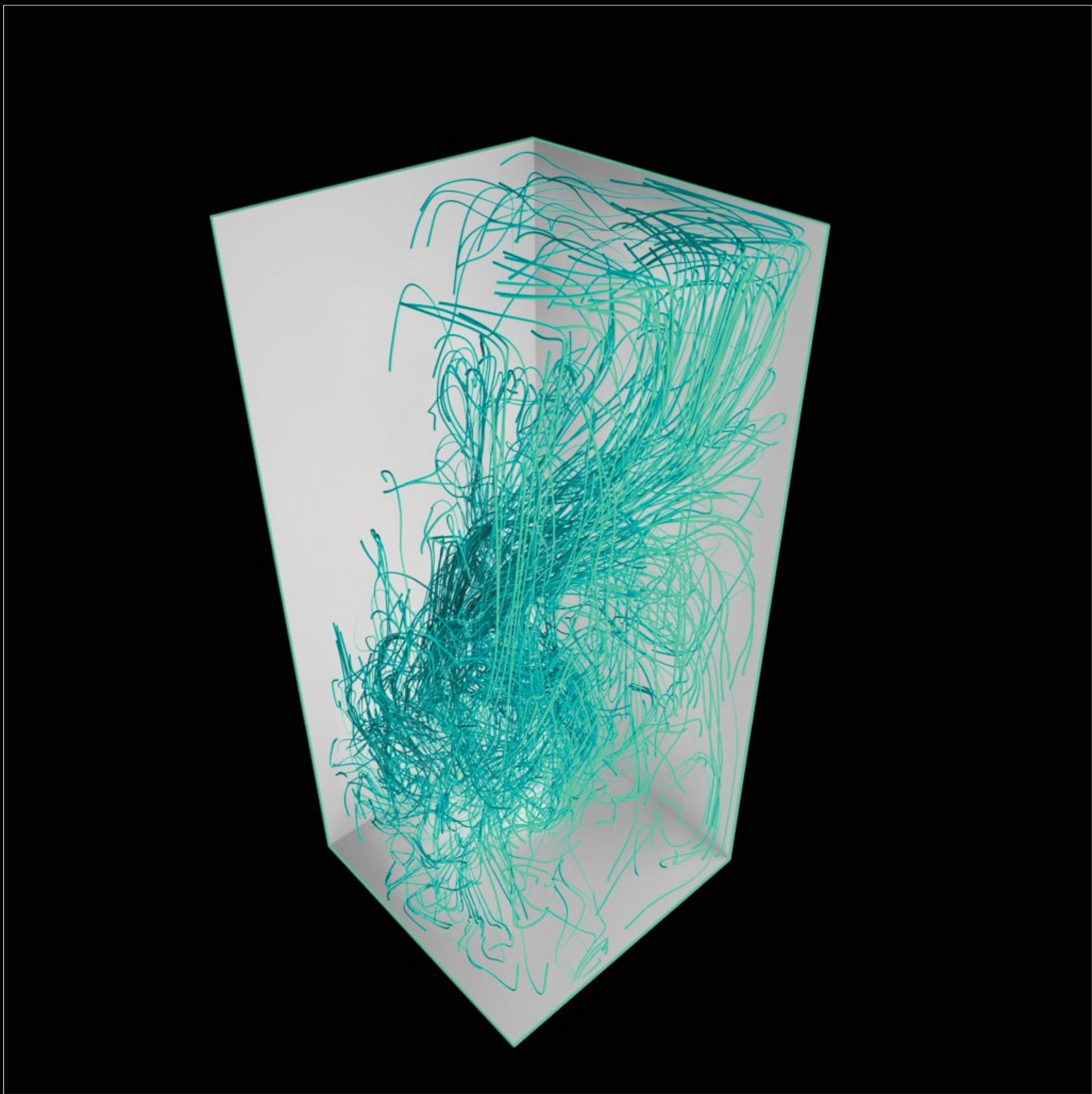


Figure 1.26: Single Territory - Full Trail Simulation.
Finished agent simulation.

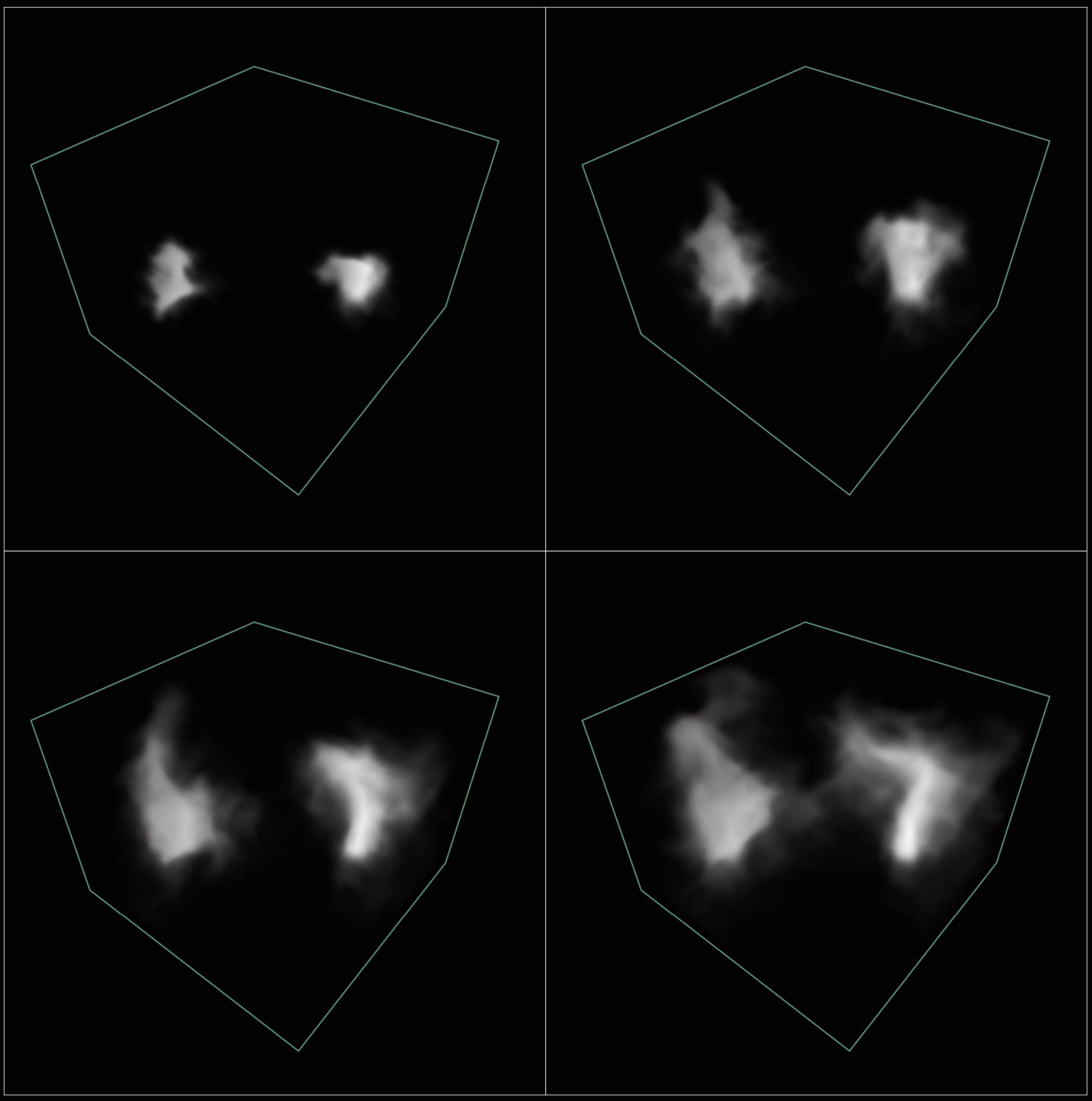


Figure 1.27: Double Territory (Fluid).
Growing two territories and bleeding borders.

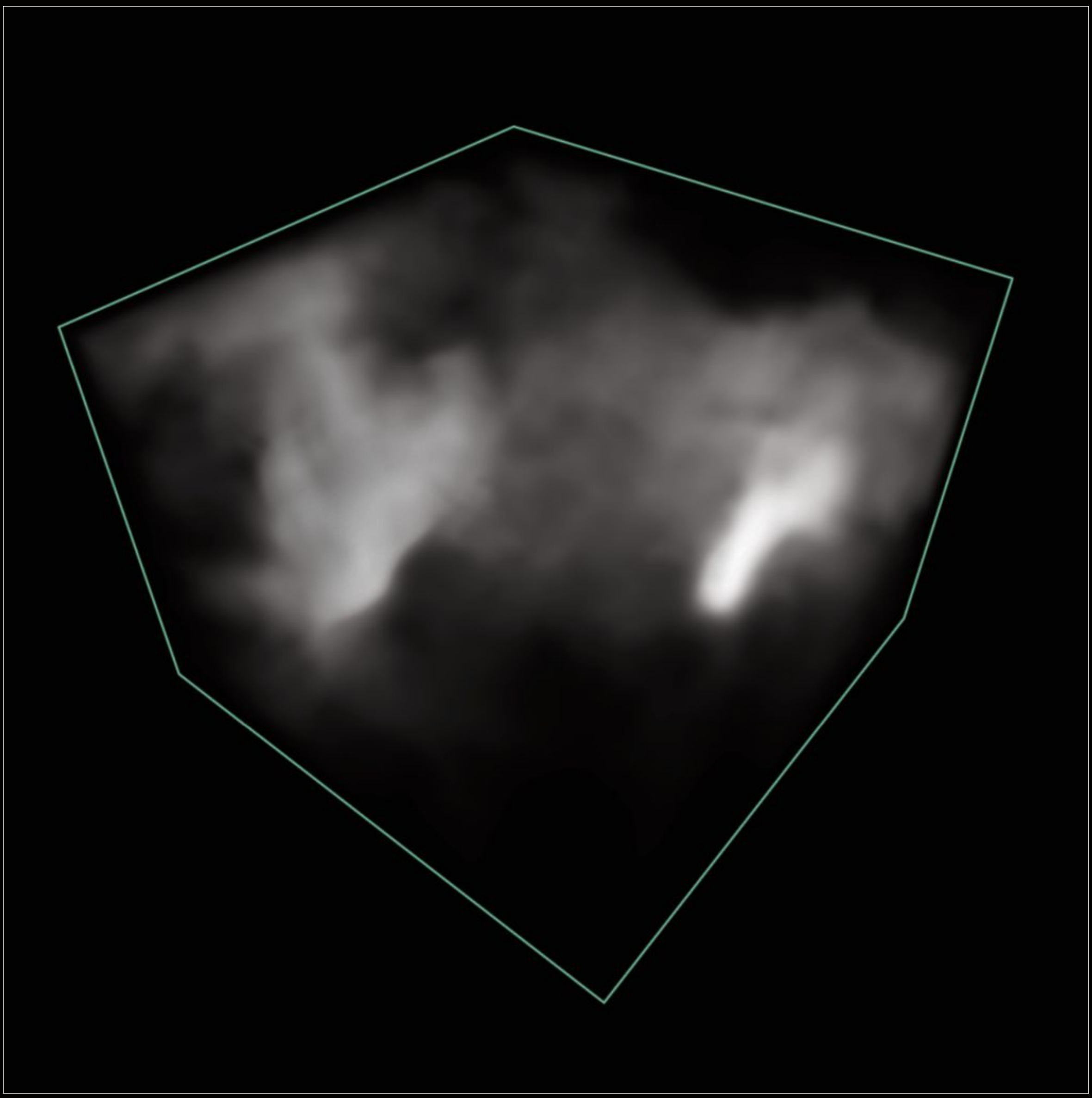


Figure 1.28: Double Territory - Full Simulation.
Final simulation state of double territories.

Two territories are simulated within this series of design experiments to test how agents react to the option of choosing between different territories. The following design experiments show a tendency for agents to choose the closest territory to occupy from its origin point and initial trajectory.

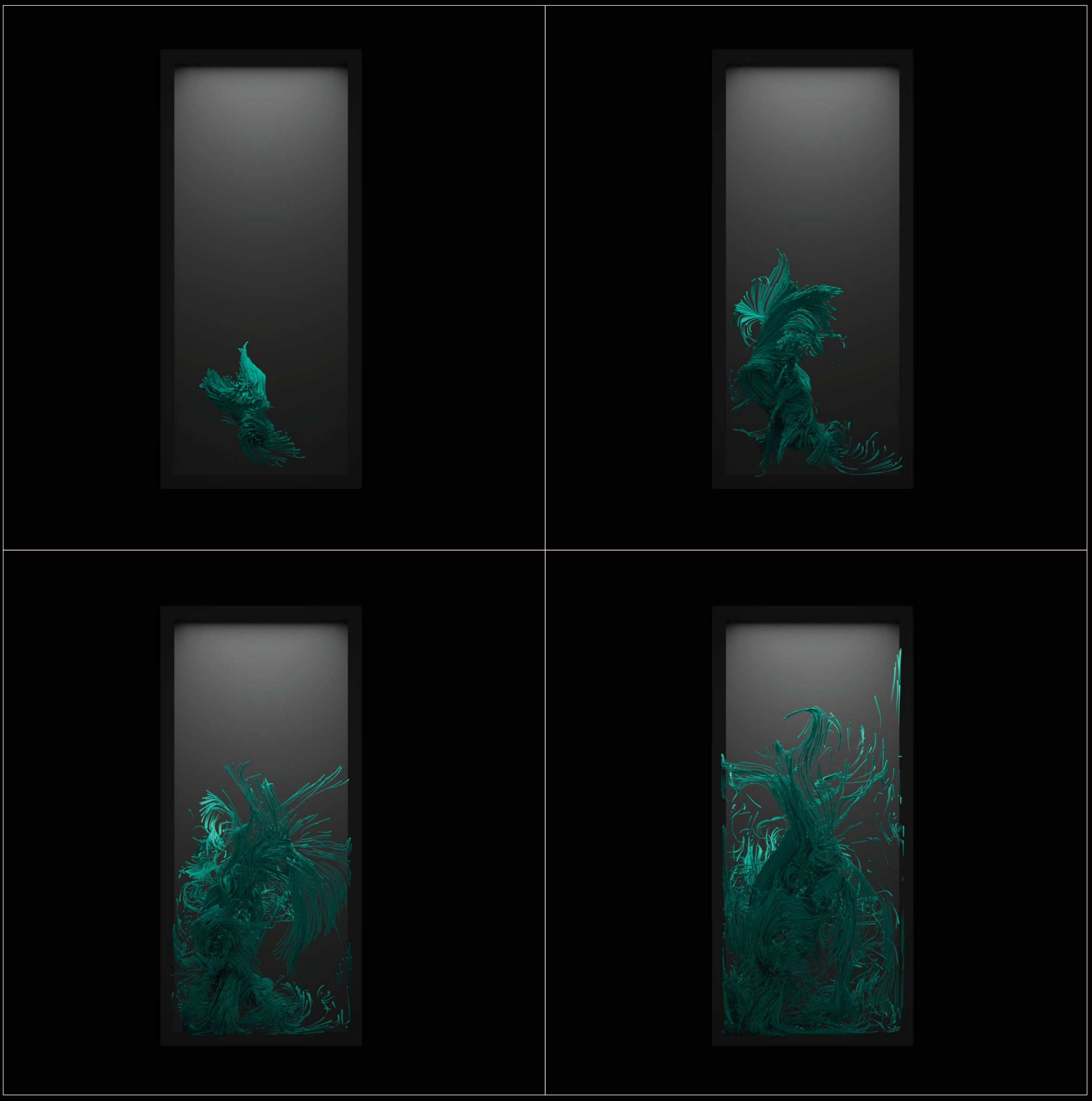


Figure 1.29: Double Territory - Trail Simulation.
Simulating agents within two territories.

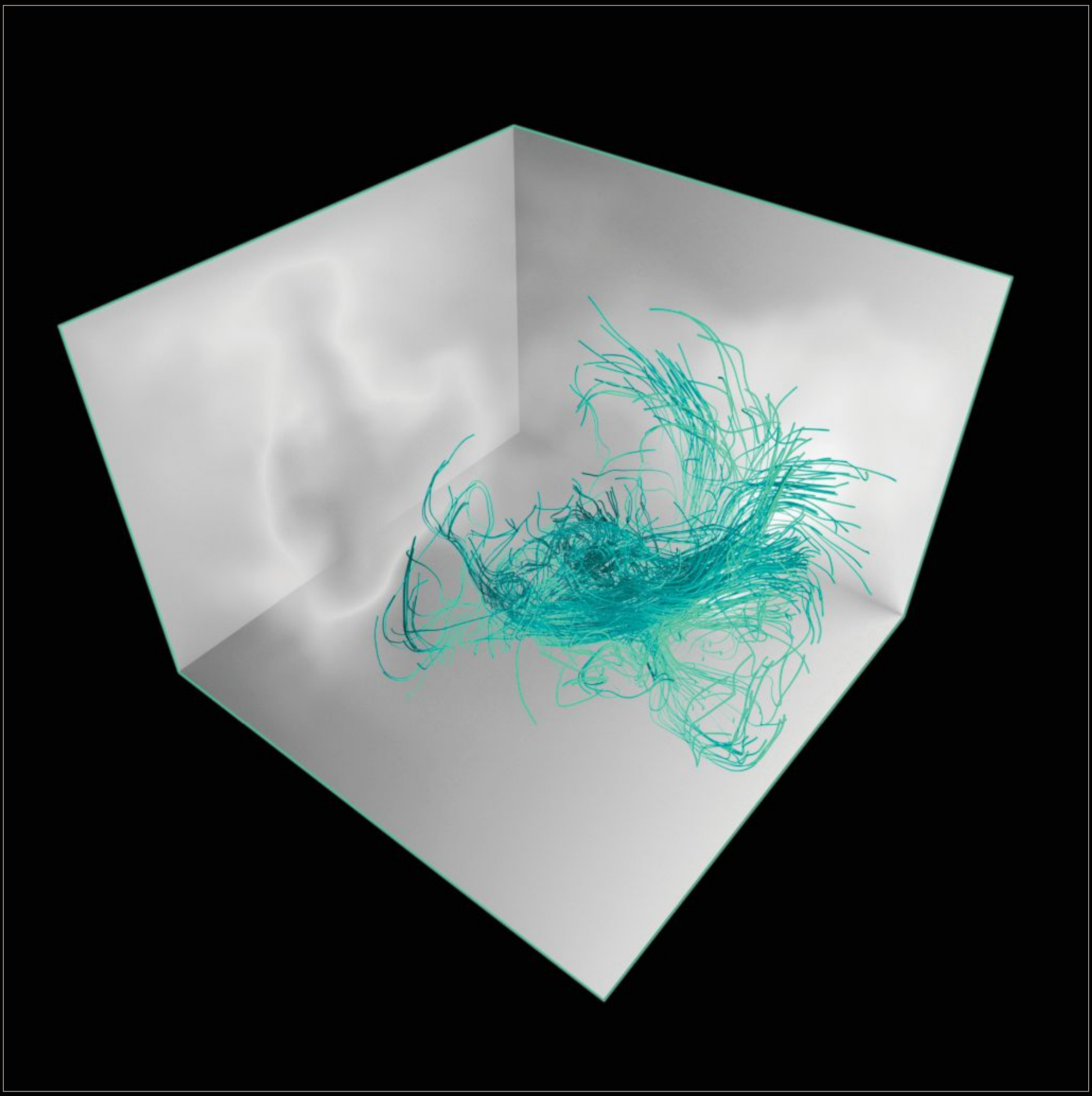


Figure 1.30: Double Territory - Full Trail Simulation.
Finished agent simulation.

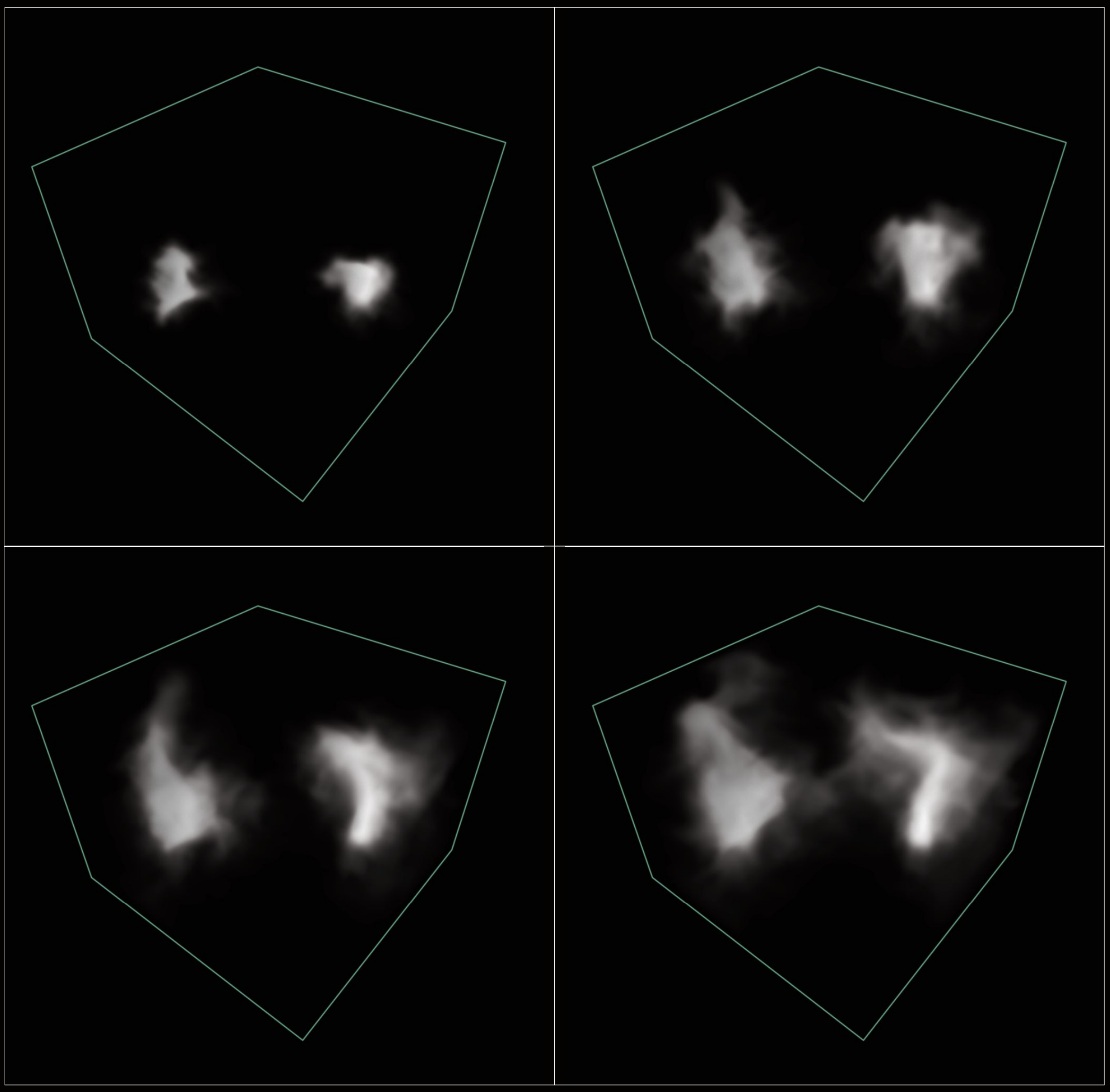


Figure 1.31: Triple Territory (Fluid).
Growing three territories and bleeding borders.

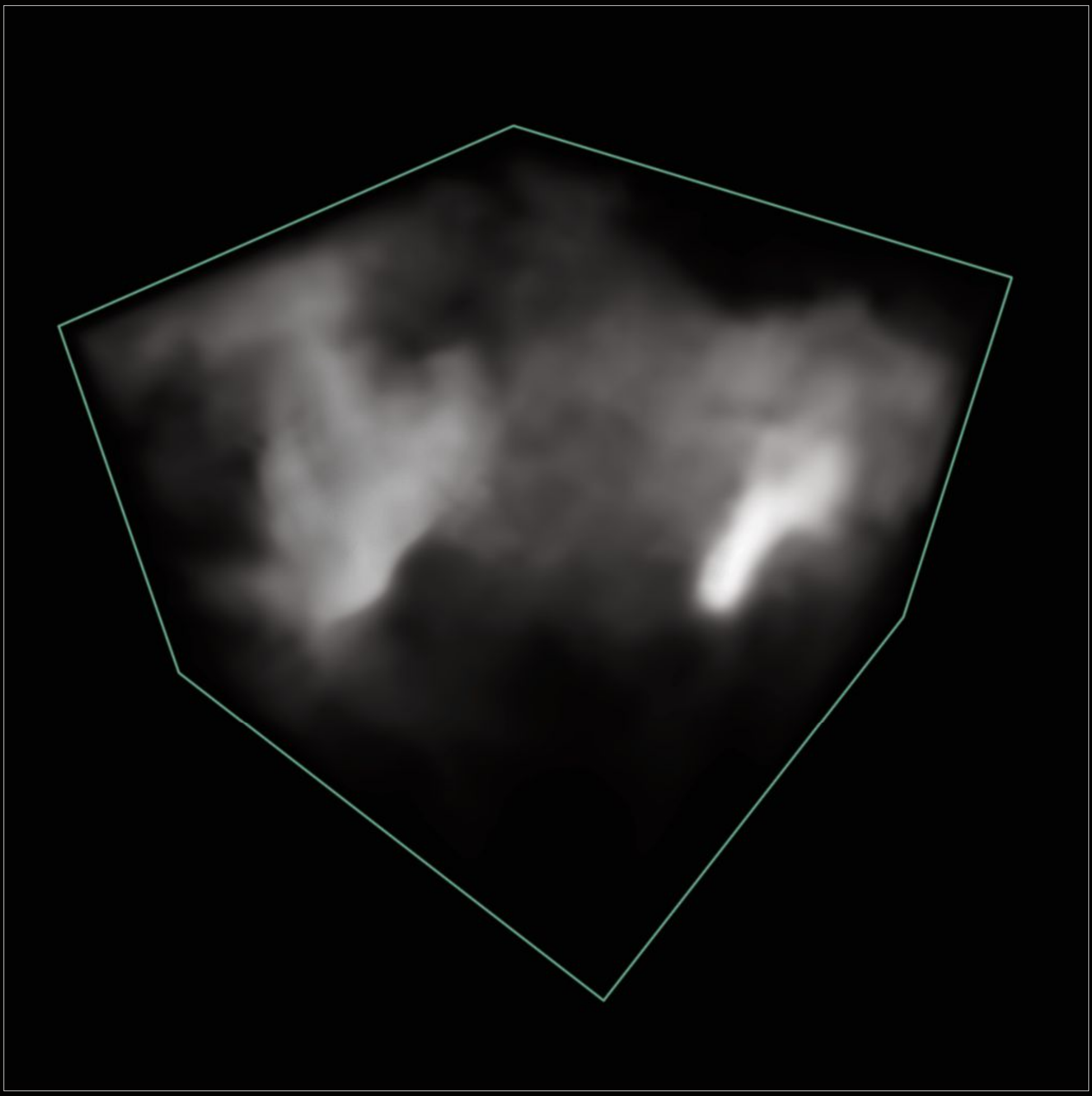


Figure 1.32: Triple Territory - Full Simulation.
Final simulation state of triple territories.

Three territories are simulated within this series of simulations to further understand how basic agents will choose which territory they occupy. The following experiments show yet again a tendency to gravitate towards the closest territory. This choice can be influenced by coding a preference towards occupying one territory over another, allowing assignment of specific agent behaviours and interaction tendencies.

Figure 1.33: Triple Territory - Trail Simulation.
Simulating agents within three territories.

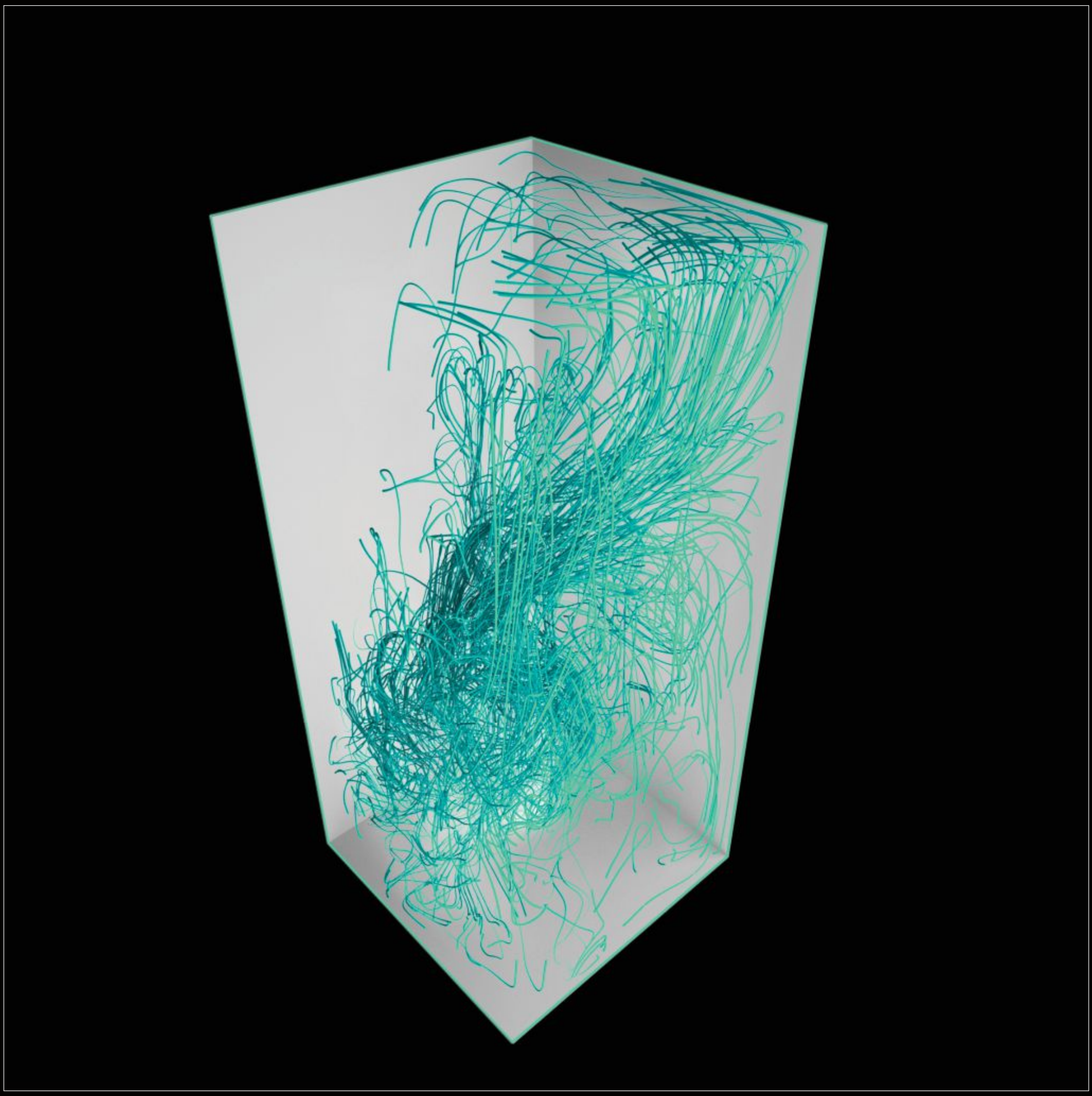


Figure 1.34: Triple Territory - Full Trail Simulation.
Finished agent simulation.

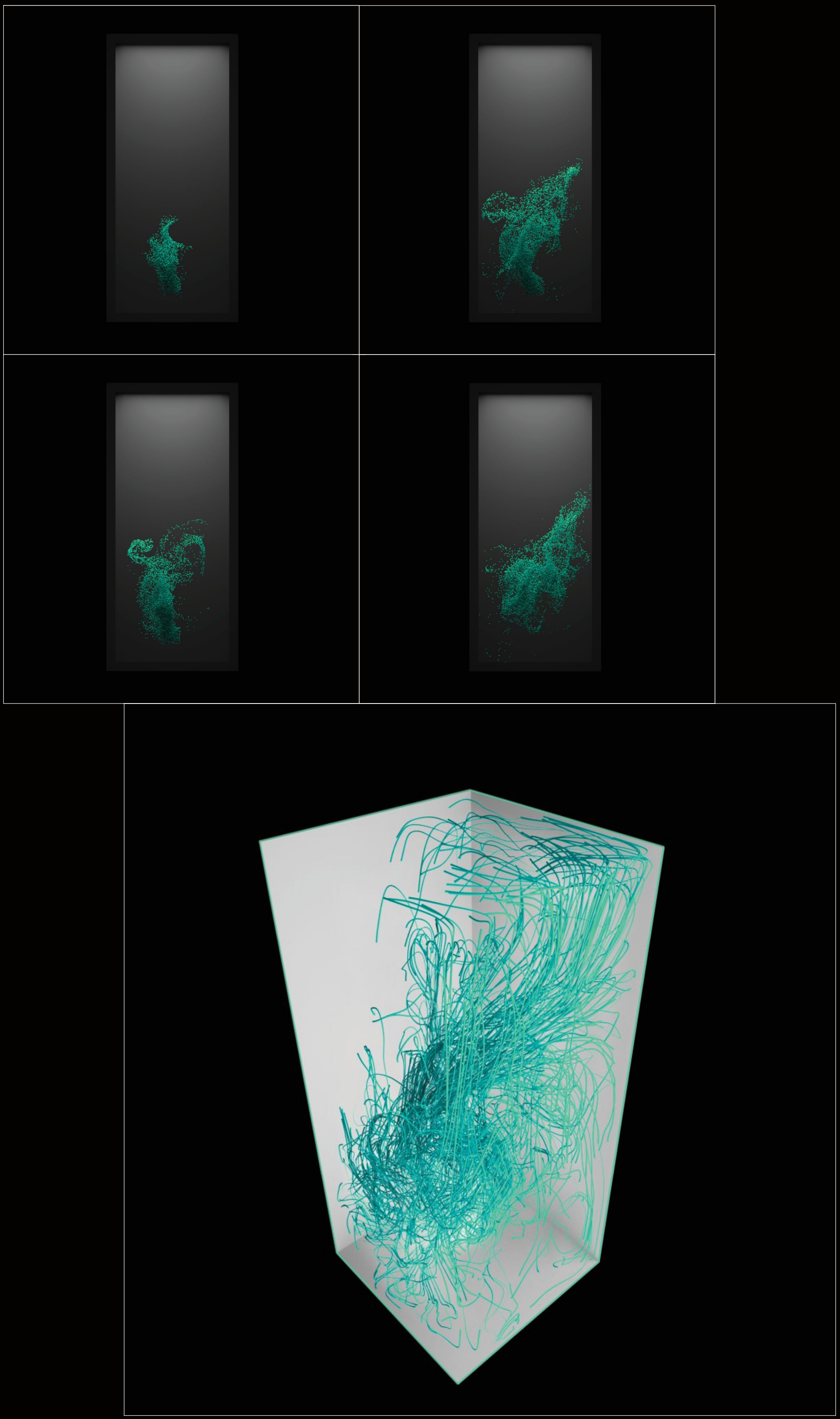


Figure 1.35: Triple Territory - Full Trail Simulation 2.
Simulating two agent types within three territories.

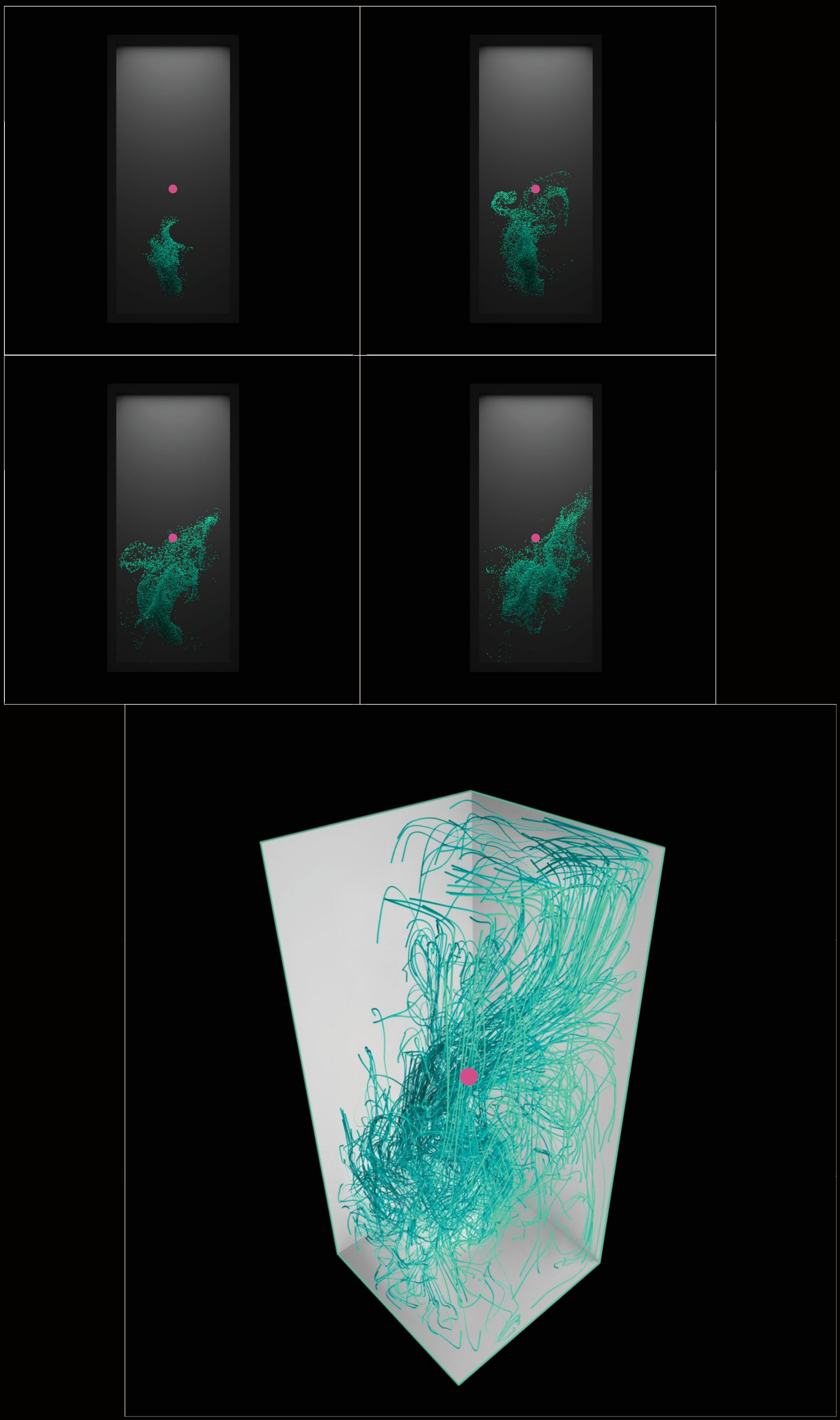


Figure 1.36: Triple Territory - Full Trail Simulation 3.
Finished agent simulations.

Environmental Influence over Time.

The following design experiments aim to explore artefacts as three dimensional objects and the effect on agents within the simulation. Different artefacts will be tested to explore how different physical objects can affect the collective behaviour of agents. Schumacher highlights the importance of artefacts within environments as signifiers of social functionality via spatial legibility. As physical objects within an environment, the following artefacts have the capacity to communicate a variety of social functions, the most basic of which being social interaction. Previous design experiments have tested the effect of artefacts on agent behaviour, however the following iterations aim to combine the physical output of agent trails with physical artefacts to test their combined spatial legibility and ability to communicate interaction through form.

Previous experiments have tested the effect of artefacts fixed to a point within the simulation. The following experiments test the effect of artefacts that are three dimensional in their influence and therefore affect how agents respond through proximity to faces and vertices rather than singular fixed points. The influence of an artefact changes how agents manifest collective interaction, with different shapes causing comparative variation.

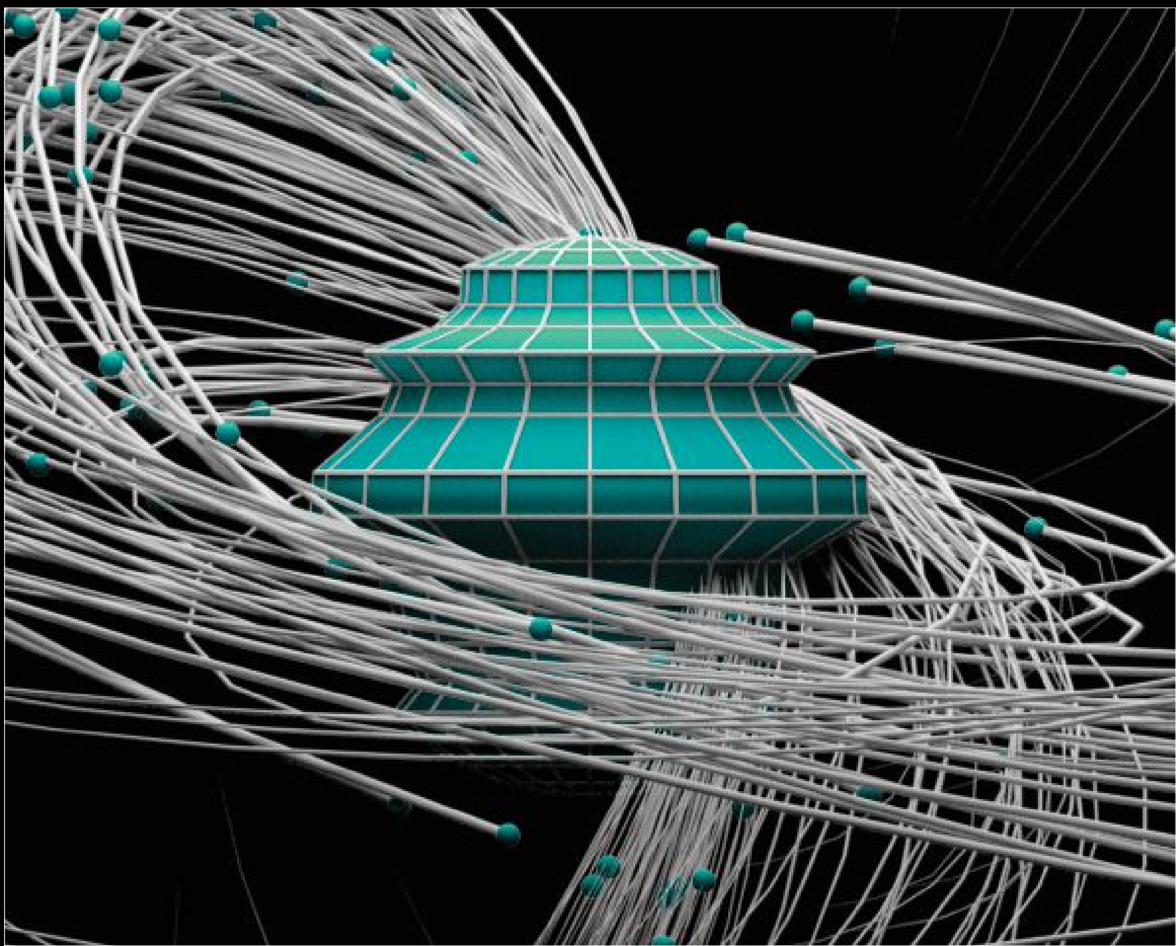


Figure 1.37: 3D Artefact in-situ.
Volumetric influencer on agent behaviour.

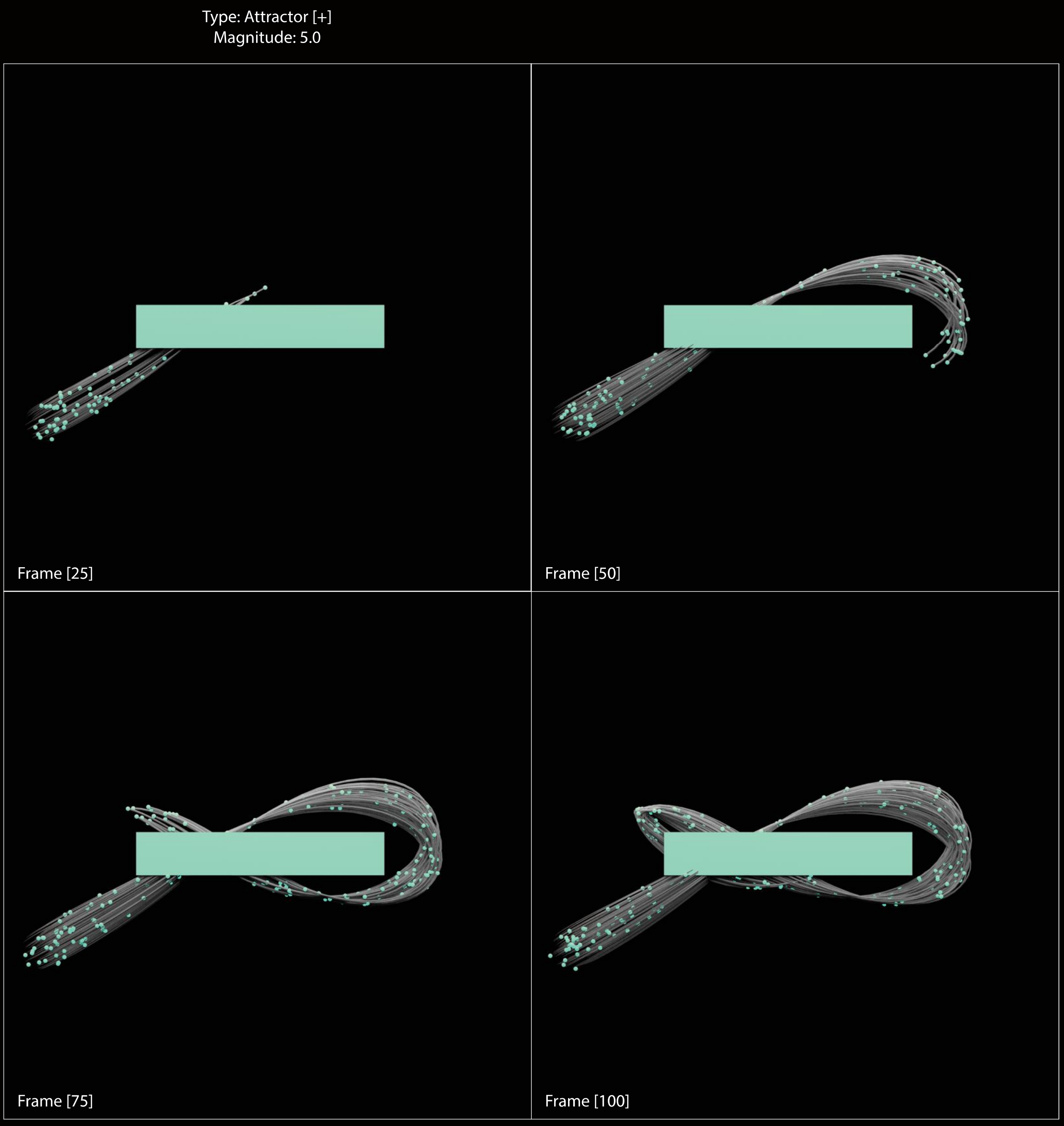


Figure 1.38: Object 1. Attraction - Series 1.
Influence of 3D artefact on agent behaviour through attraction.

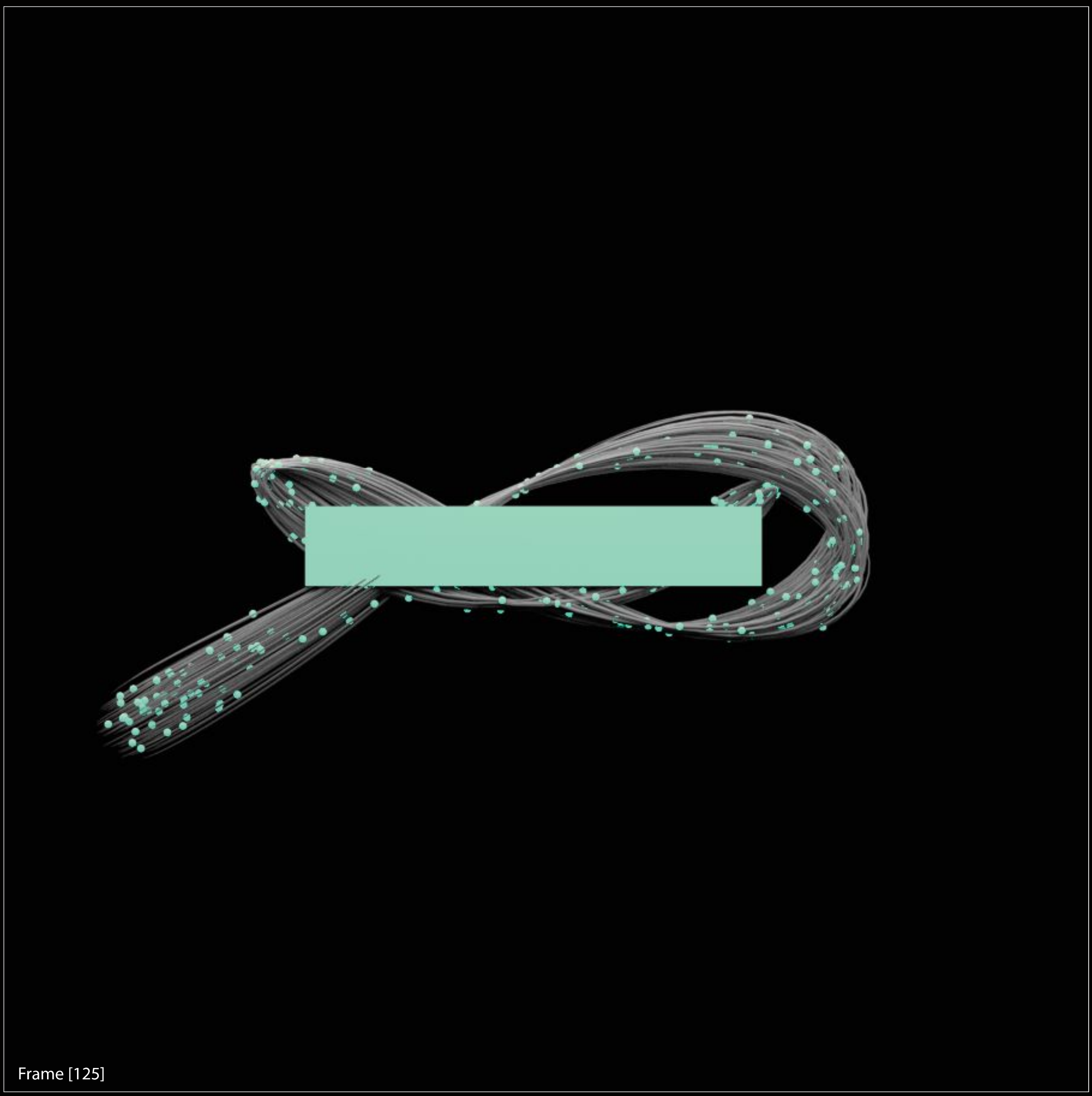


Figure 1.39: Object 1. Series 1. Final.

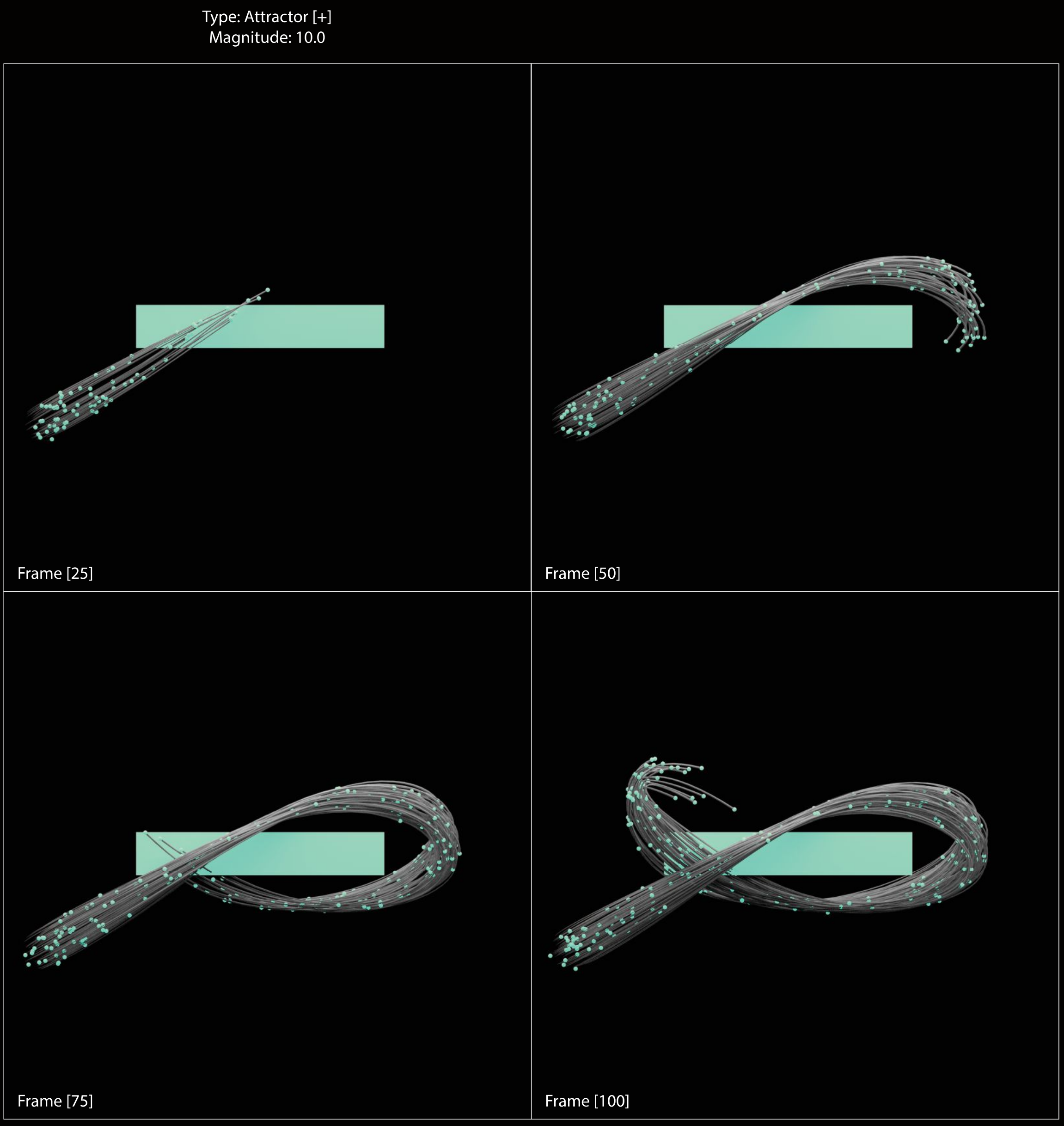


Figure 1.40: Object 1. Attraction - Series 2.
Influence of 3D artefact on agent behaviour through attraction.

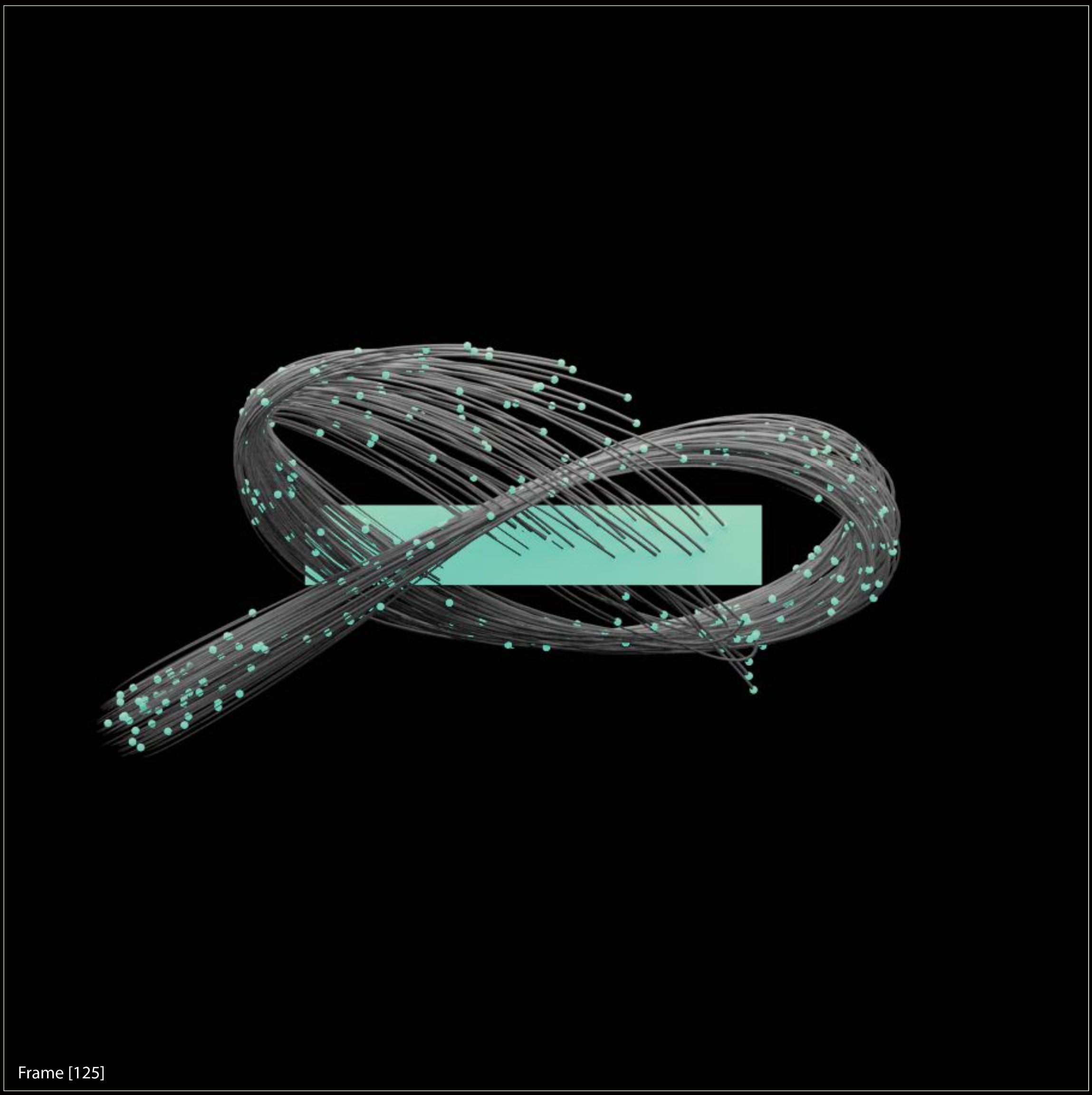


Figure 1.41: Object 1. Series 2. Final.

Type: Attractor [+ and -]
Magnitude: 10.0

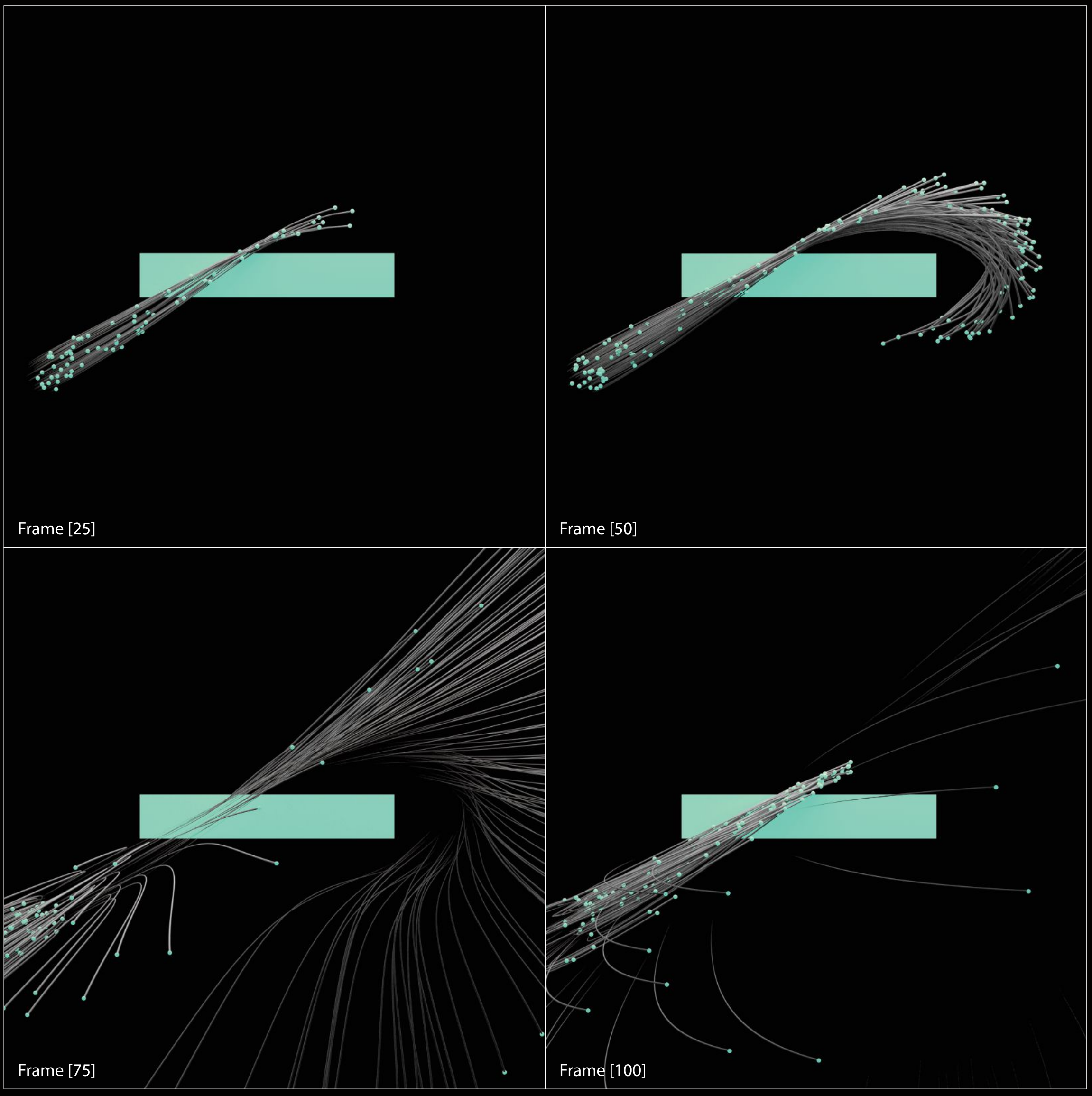


Figure 1.42: Object 1. Attraction & Repulsion - Series 3.
Influence of 3D artefact on agent behaviour through attraction and repulsion.

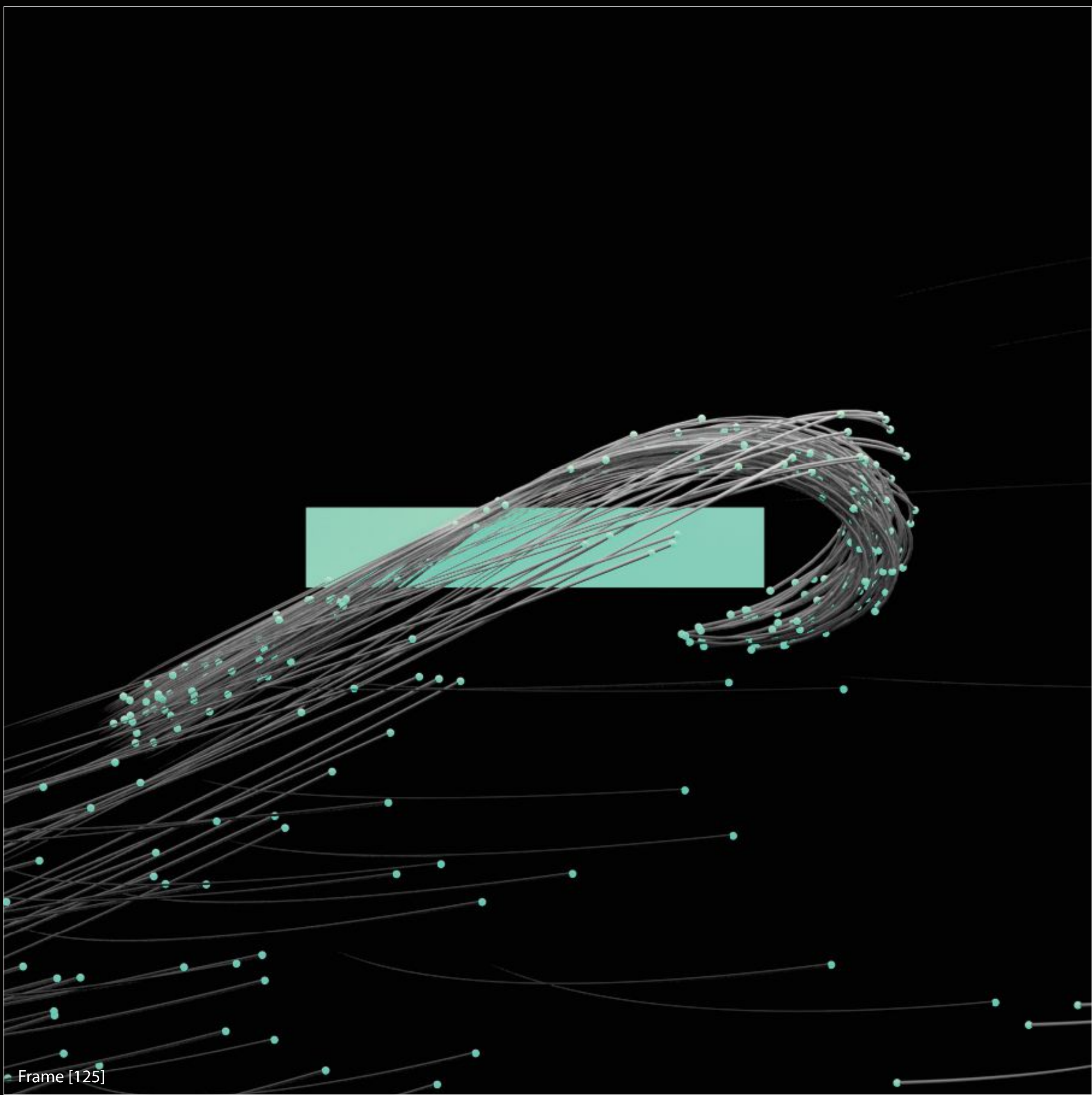


Figure 1.43: Object 1. Series 3. Final.

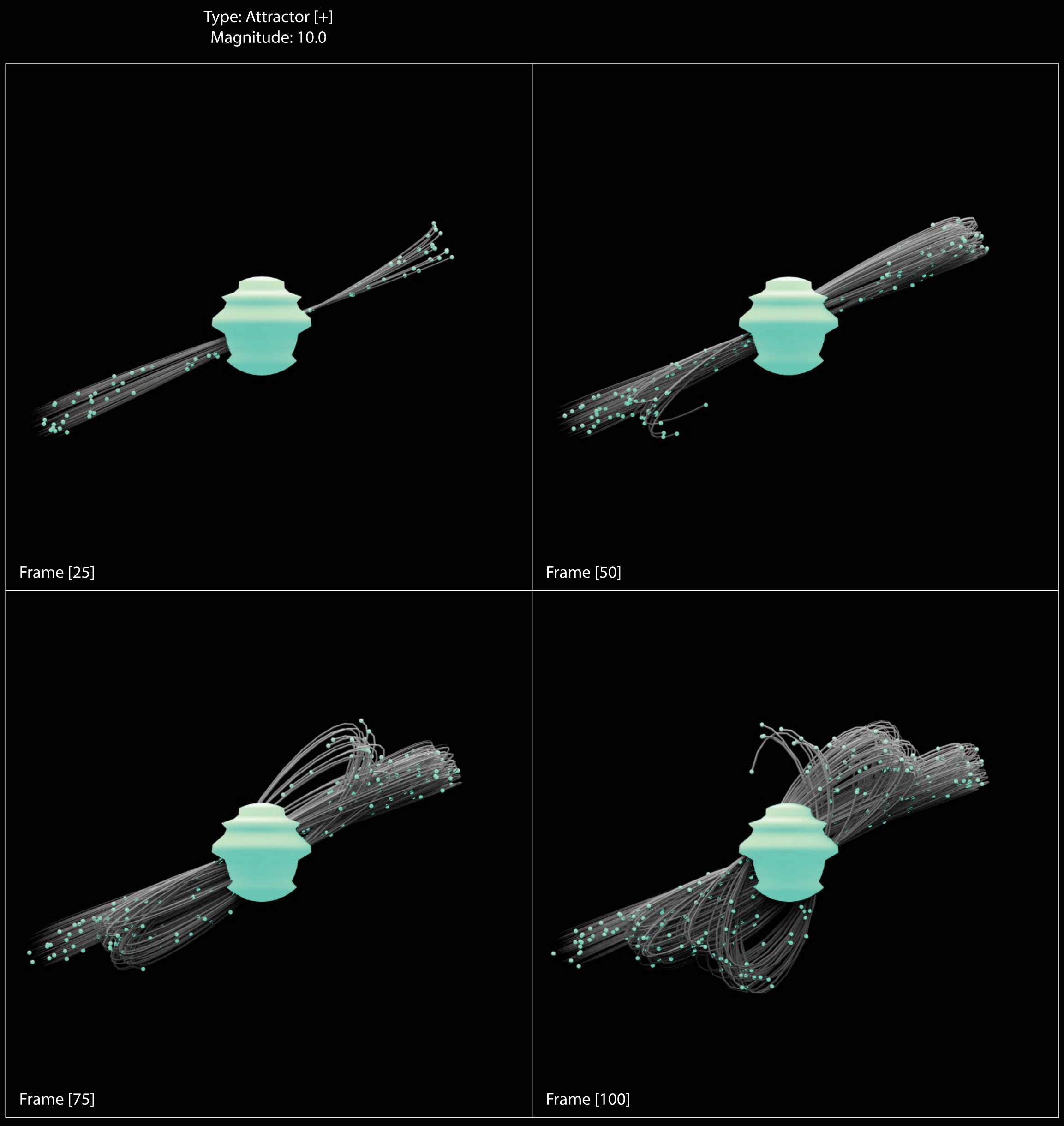


Figure 1.44: Object 2. Attraction - Series 4.
Influence of stylised 3D artefact on agent behaviour through attraction.

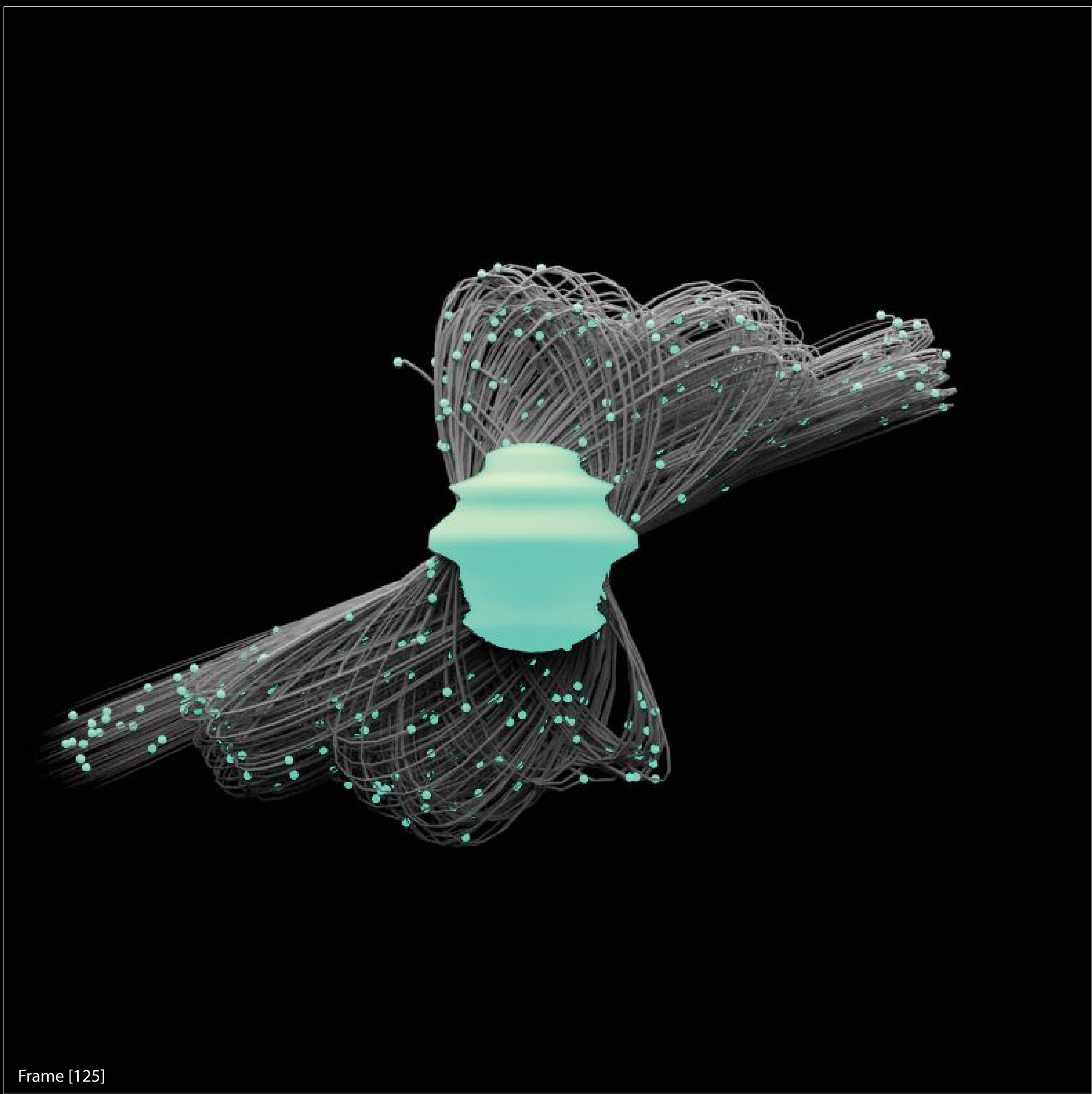


Figure 1.45: Object 2. Series 4. Final.

Type: Attractor [+] & Orbit [x]
Magnitude: 10.0

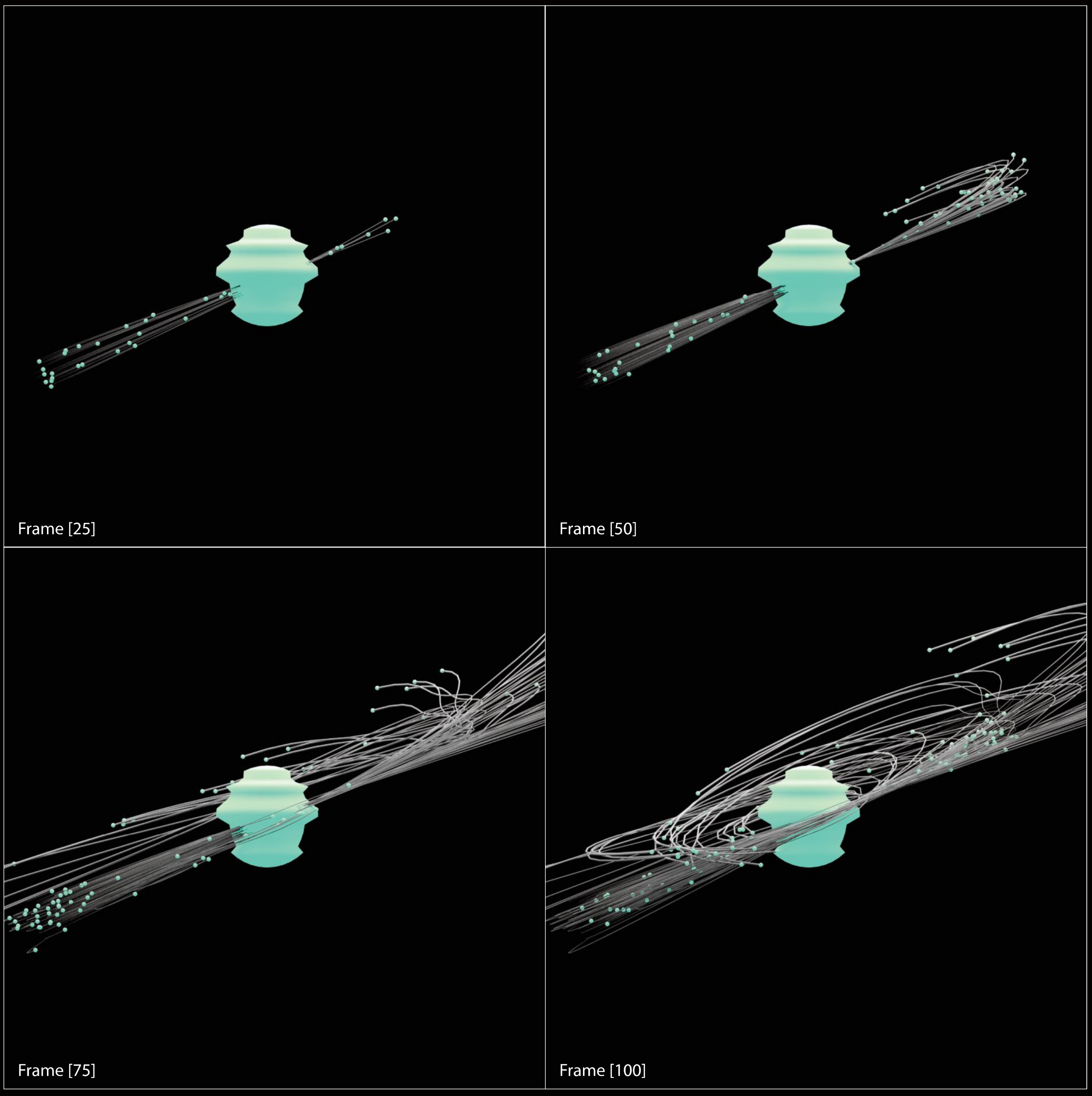


Figure 1.46: Object 2. Attraction and Orbit - Series 5.
Influence of stylised 3D artefact on agent behaviour through attraction and orbit.

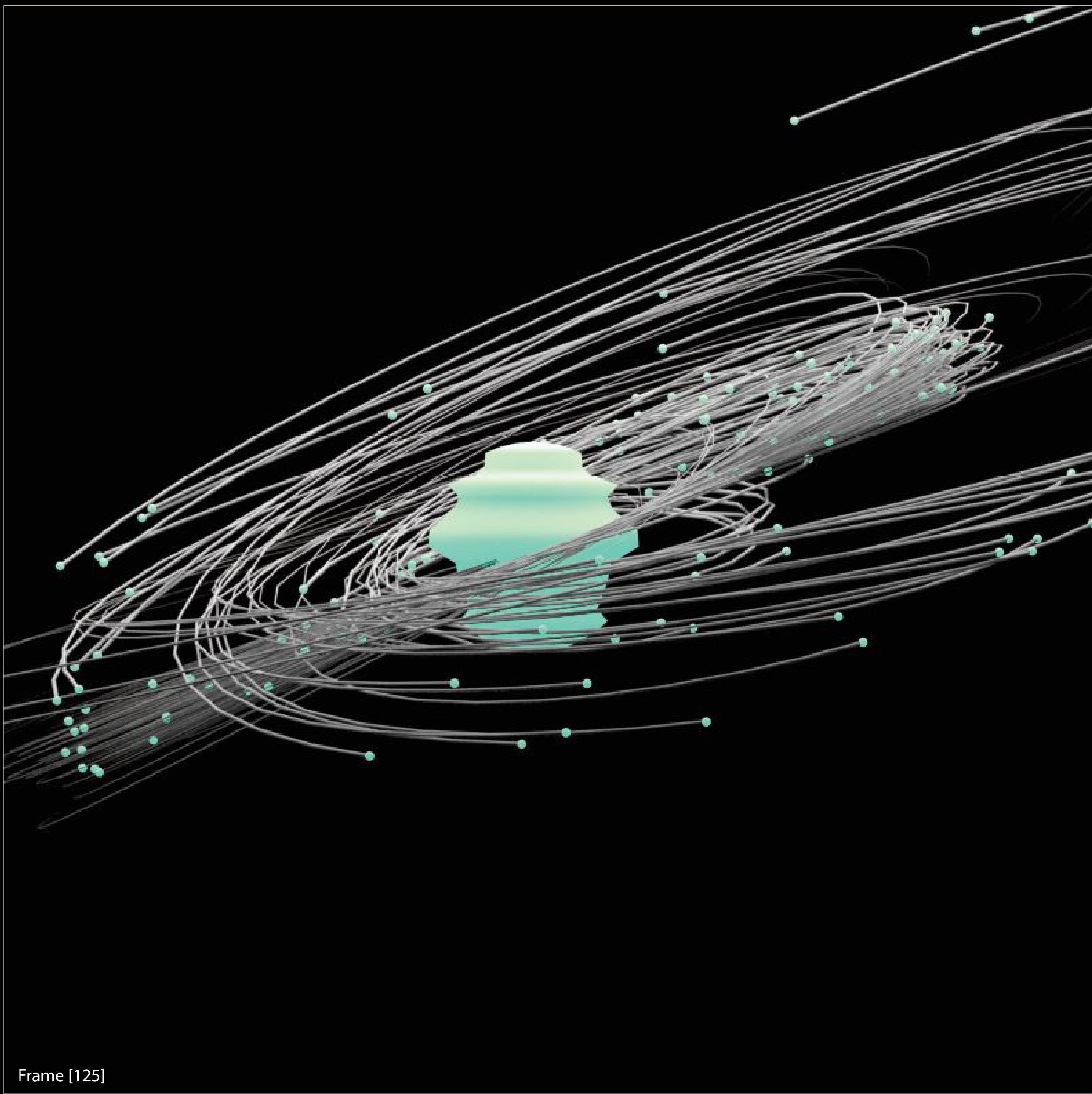


Figure 1.47: Object 2. Series 5. Final.

Instancing Typologies.

The following design experiments explore the instancing of typologies, using localised clusters to indicate varied social functions implied through different geometries. These experiments bring together various techniques explored within earlier design iterations to summarise an agent-based methodology for instancing abstract urban elements into a behaviour driven simulation output. The different objects reference different social functions to indicate how an urban environment can communicate behaviour driven interaction to its urban demographic through spatial legibility. Therefore the aim of these design experiments is to test the extent to which pre-set typologies can be instanced into a simulation output and the degree to which localisation of typologies can indicate various social functionalities through form.

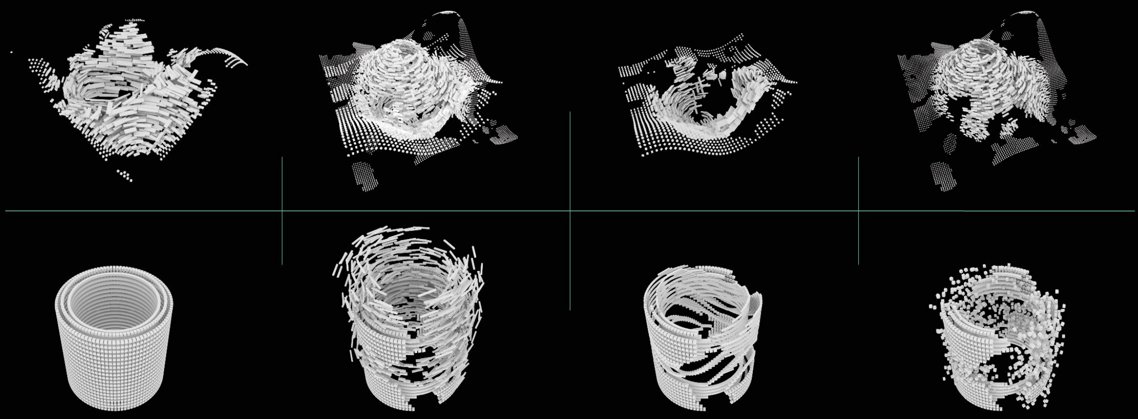


Figure 1.48: Manipulating Instanced Typologies.
Testing various methods of distribution for localised typologies.

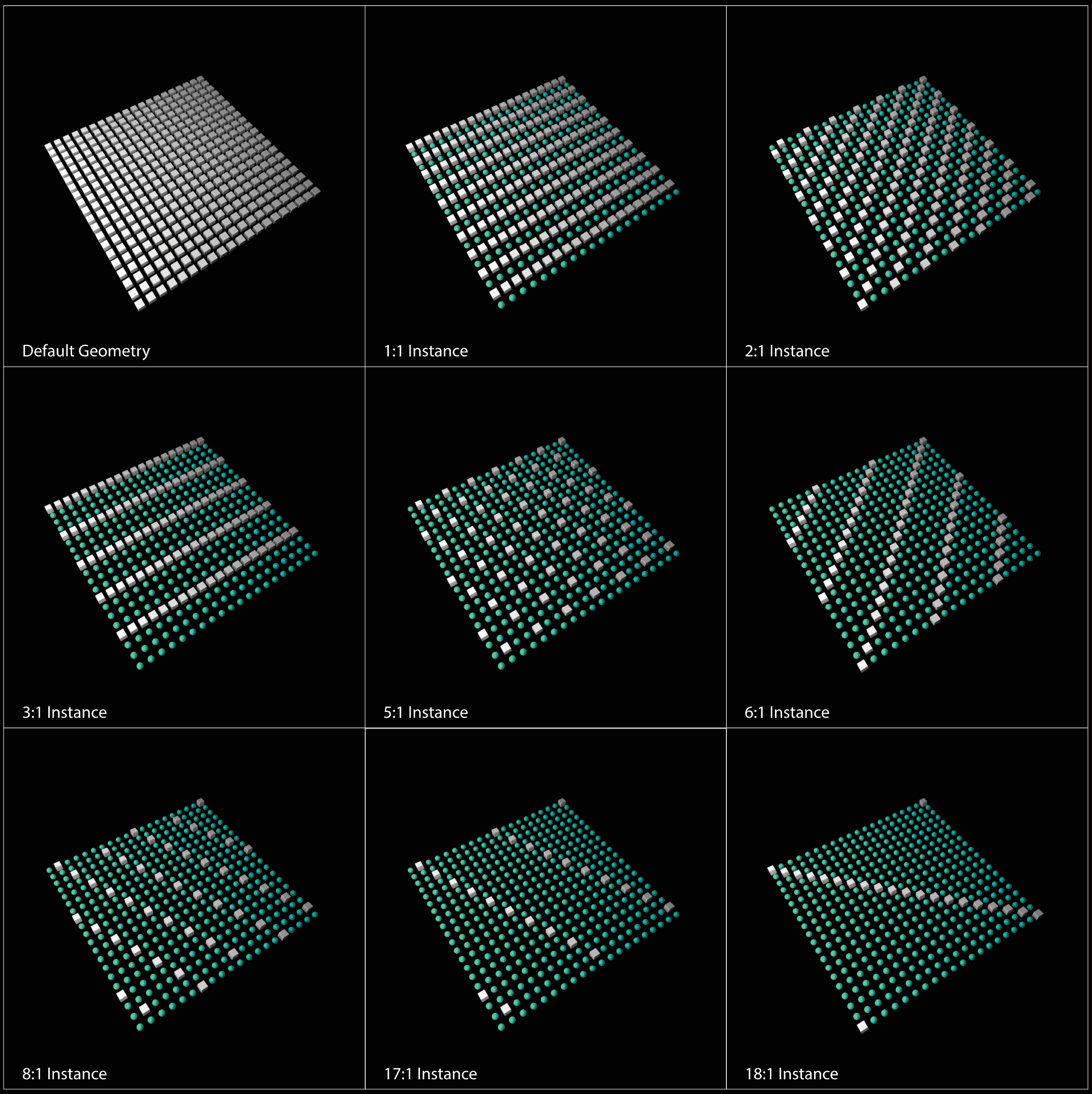


Figure 1.49: Distribution Control - Series 1.
Linear distribution of instanced typologies.

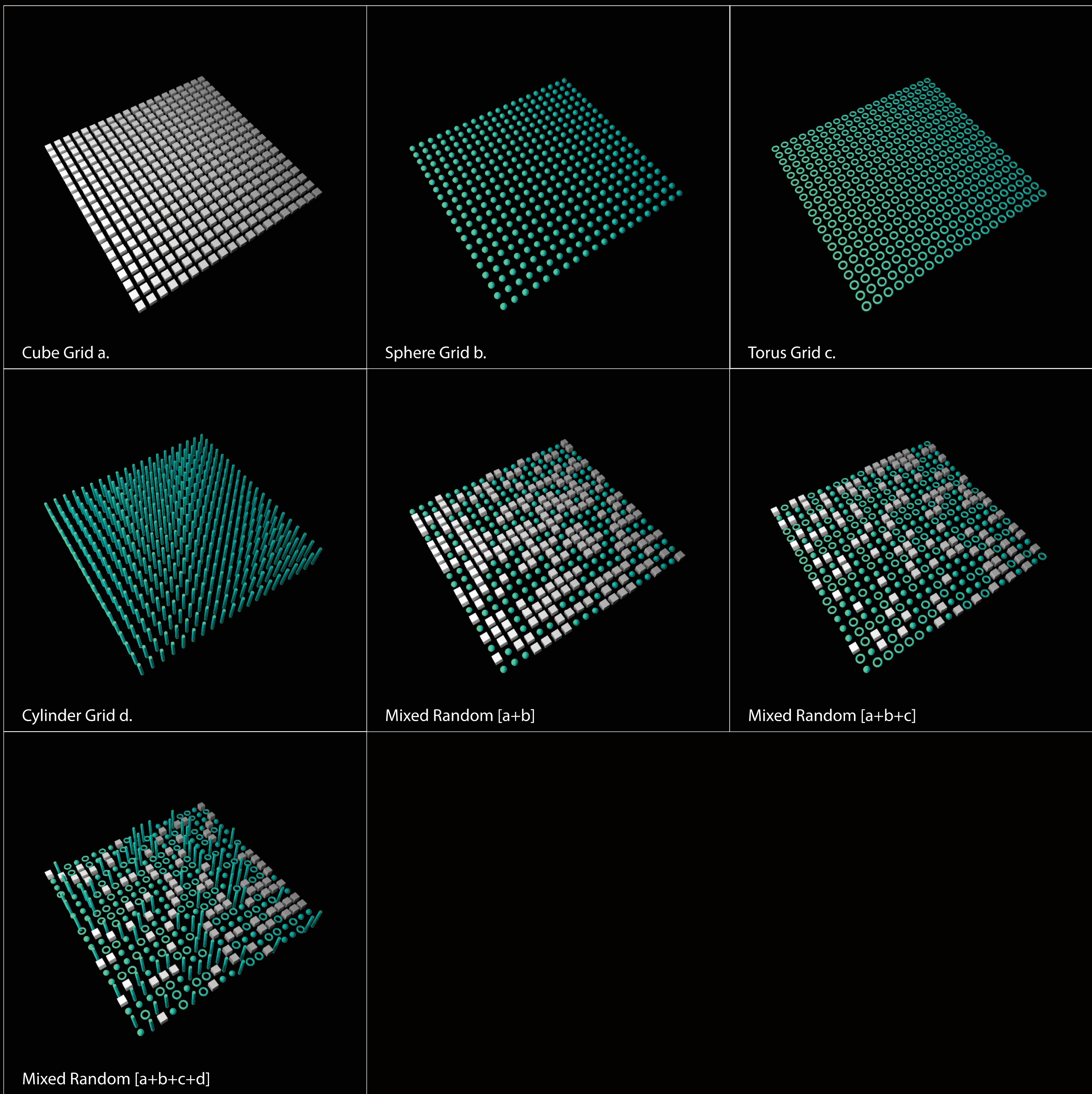


Figure 1.50: Distribution Control - Series 2.
Random distribution of instanced typologies.

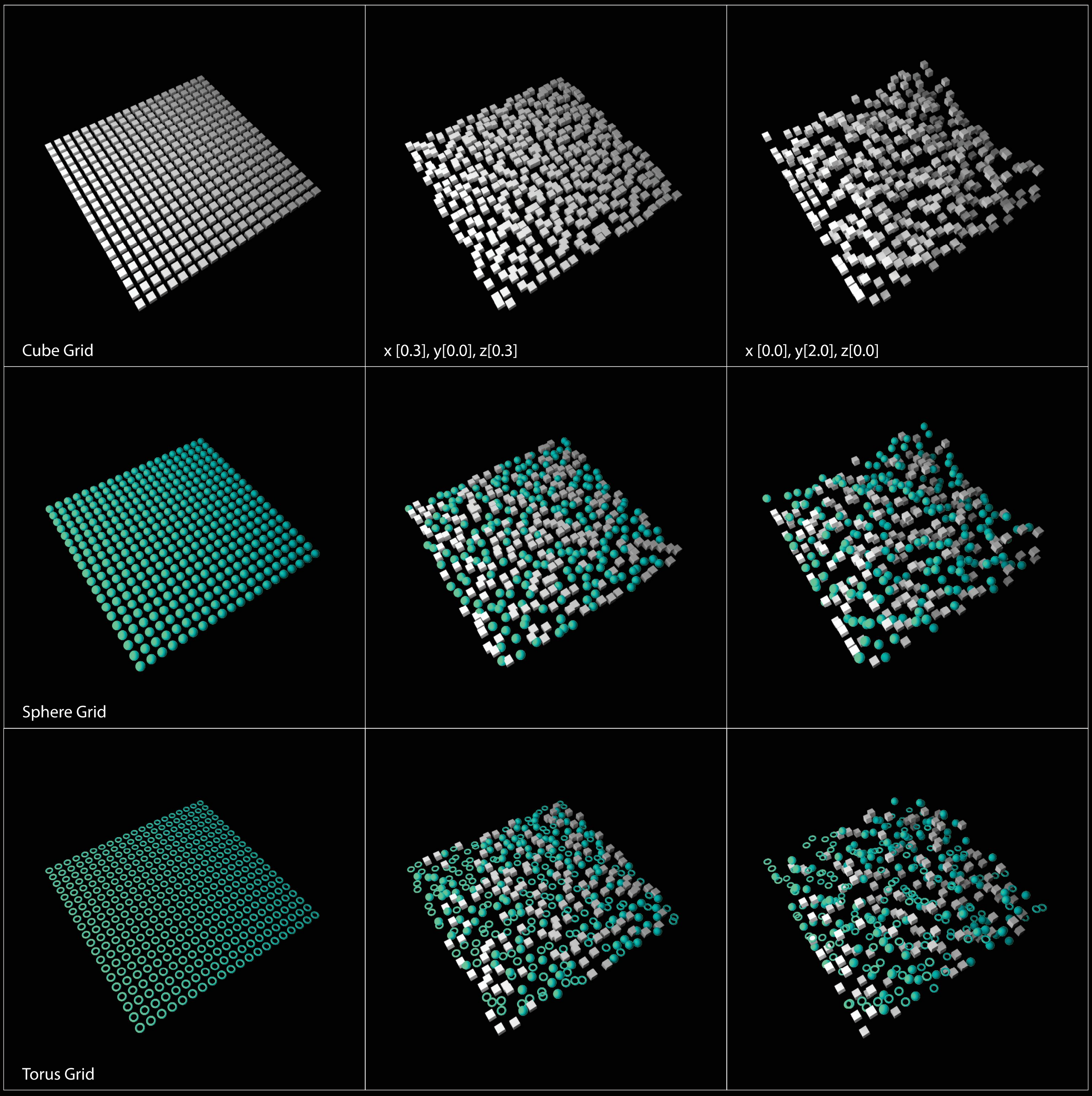


Figure 1.51: Distribution Control - Series 3.
Random distribution of instanced typologies.

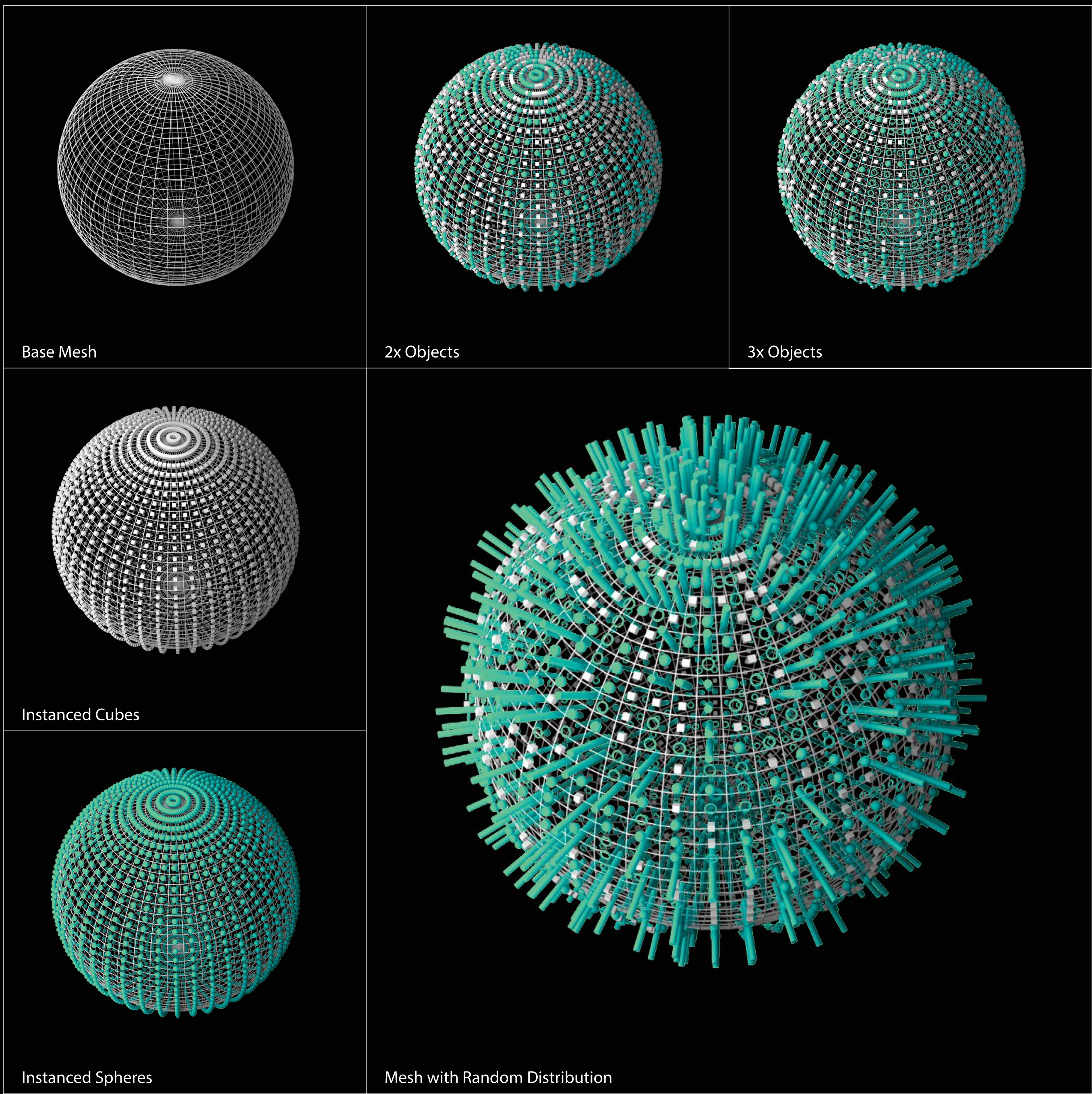


Figure 1.52: 3D Distribution - Series 4.
Random distribution of instanced typologies onto custom geometry.

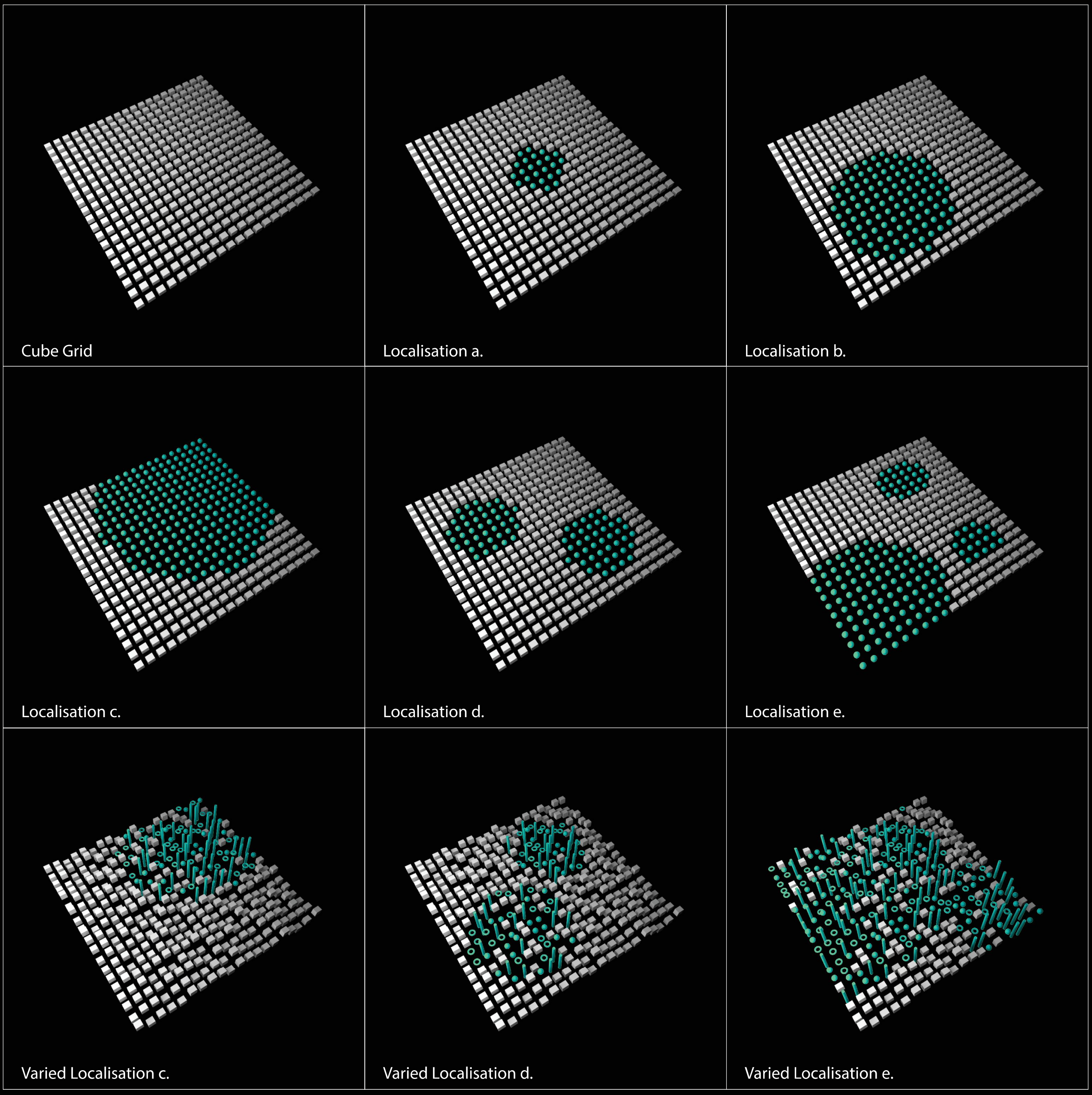


Figure 1.53: Localised Distribution - Series 5.
Localised areas of random distribution on grid.

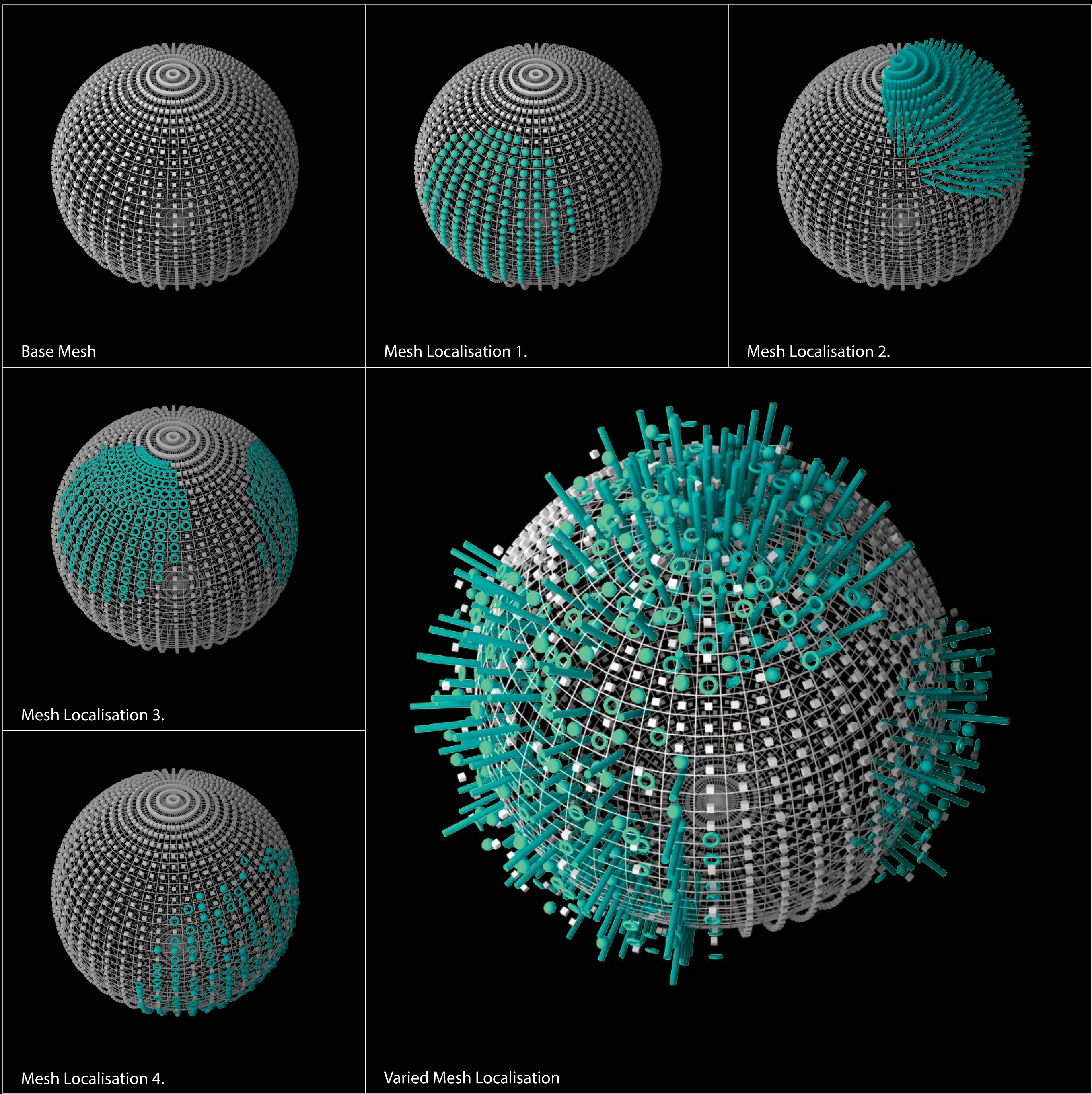


Figure 1.54: 3D Localised Distribution - Series 6.
Localised areas of random distribution onto custom geometry.

Figure 1.55: Agent Simulation Output.

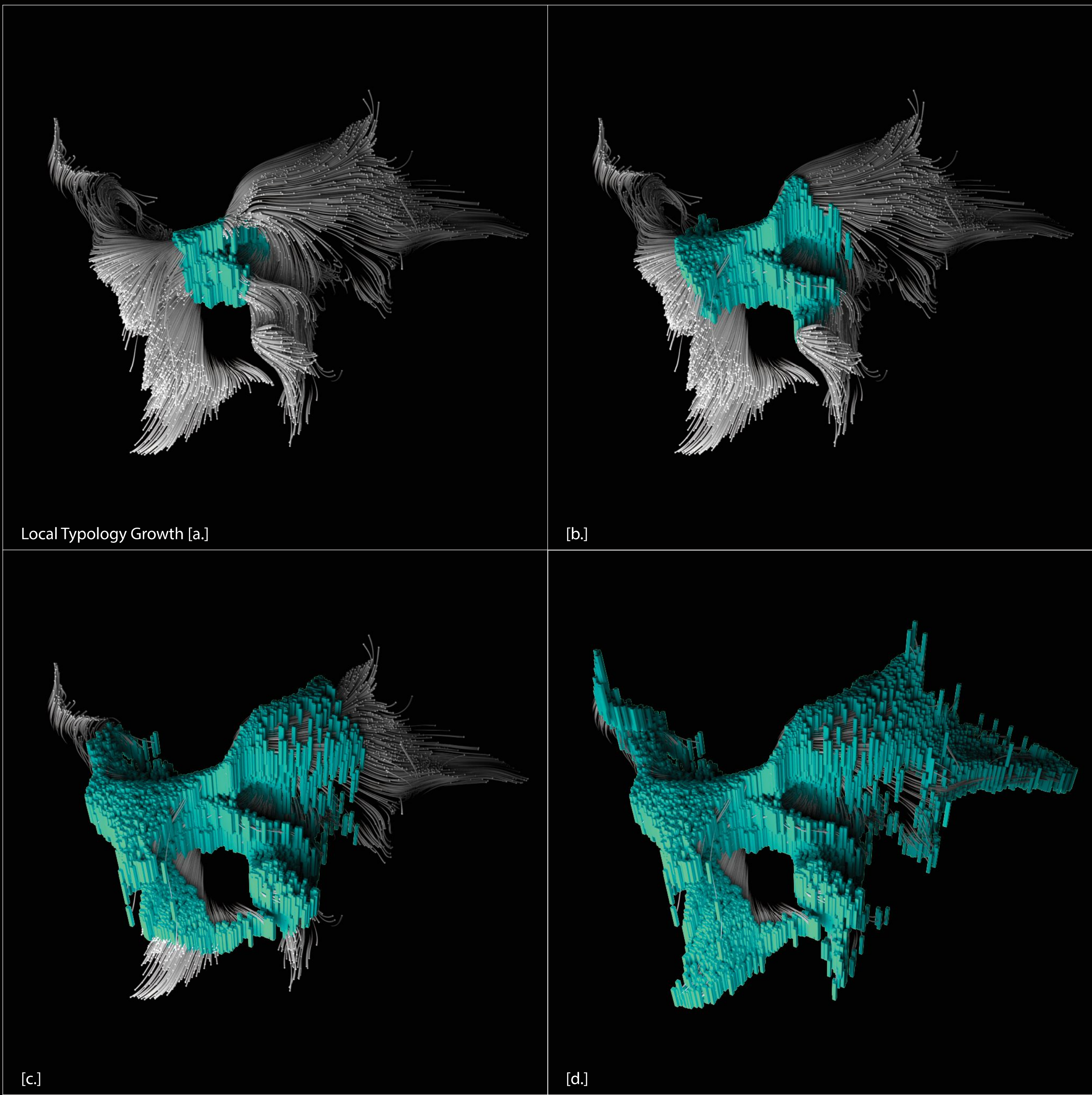


Figure 1.56: Agent - Typology Instancing - Localisation Series 6.
Instancing typologies into an agent-based simulation output.

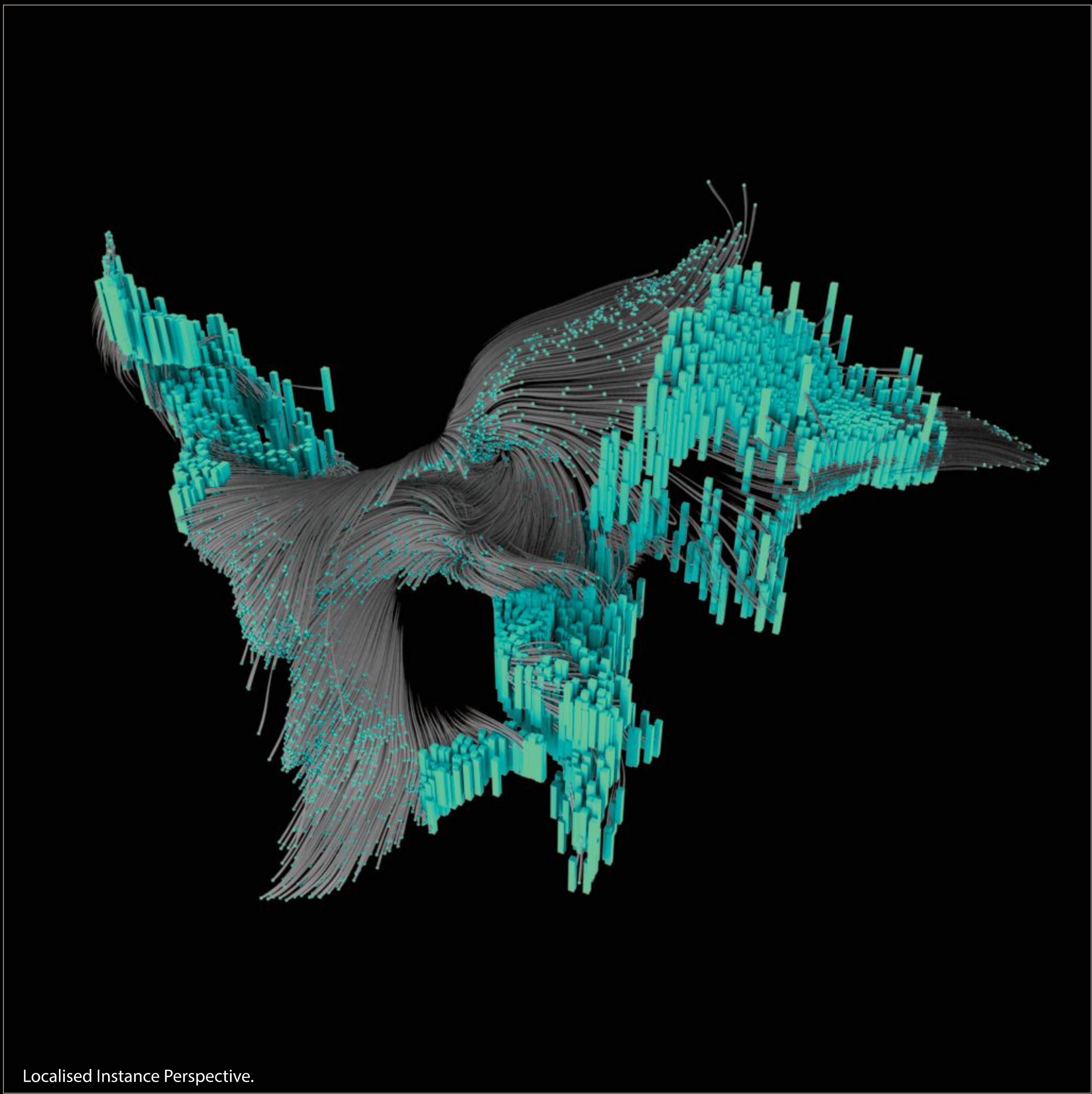


Figure 1.57: Localised Agent - Typology Instance.

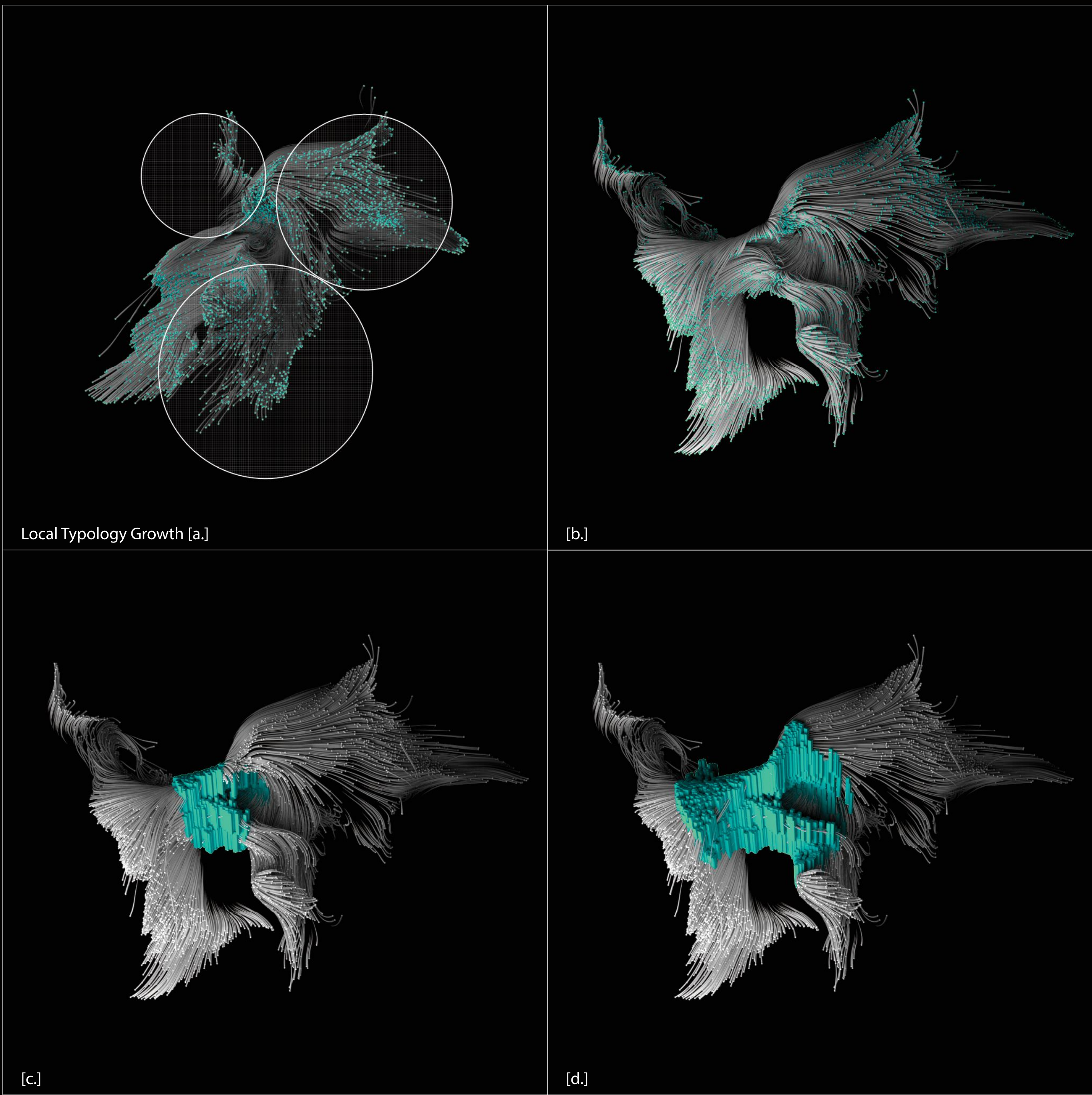


Figure 1.58: Agent - Typology Instancing - x3 Localisations Series 7.
Instancing typologies into an agent-based simulation output operating within 3 localisations.

Developed Design.

A final design experiment will be developed at this stage of the research using a combination of previously explored design experiments and context-specific parameters. Each development will outline a design issue and corresponding design decision as the methodology adapts to answer the research agenda. This chapter will first introduce agents and artefacts given agency through specified parameters, followed by the final agent-based simulation to establish a pre-geometry state of interaction that will be developed further to inform design issues.

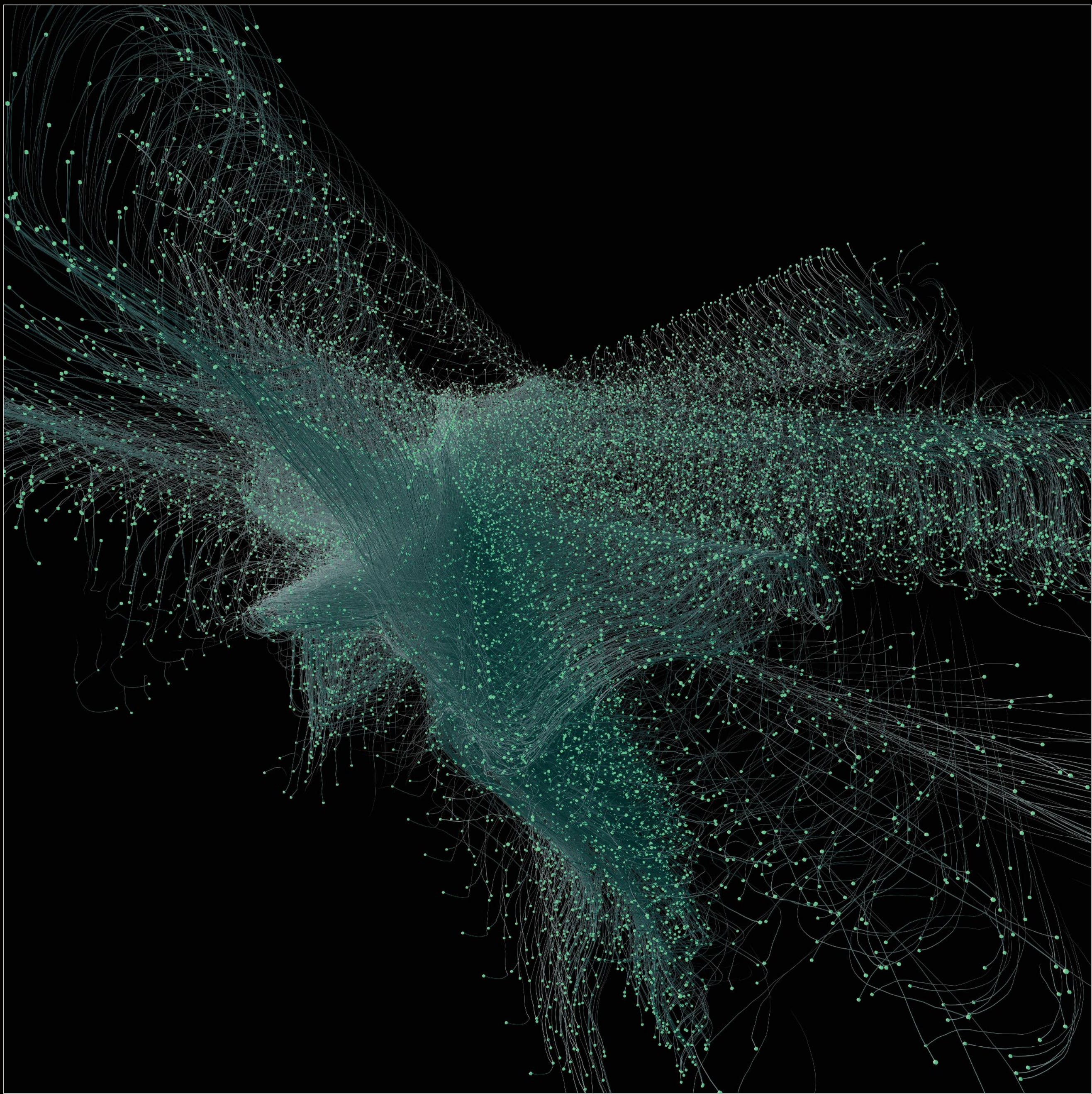


Figure 2.1: Recursive Agent Trails.
Abstract behaviours within collective interaction.

Unpacking Agent Behaviour.

This segment looks to establish the behaviour of various agent types that will be simulated using agent-based modelling. Unpacking unique agent behaviours is an objective this research explores to contextualise the resulting collective behaviour of a population. Attributes unpacked within this segment highlight various agent types, their behavioural tendencies and the architectural environment they operate within. These attributes establish an abstract view of individualistic behaviour and will later inform typologies that will instance into the pre-geometry simulation output.

Figure 2.2: Chandni Chowk Market.
India's busiest market in the heart of New Delhi.

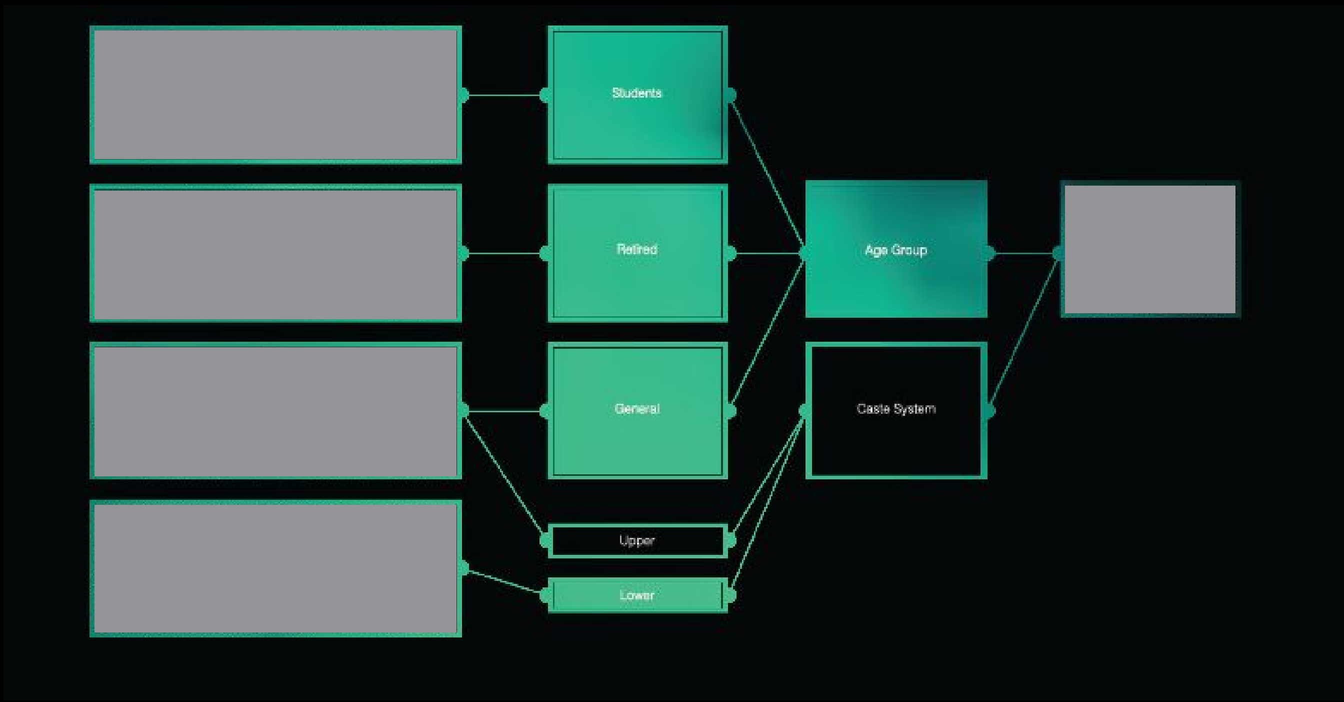


Figure 2.3: Social Agents of New Delhi.
Identifying the various social agents being considered within this investigation.

The social agents of New Delhi have been analysed and broken down into two categories, age group and (to a lesser extent) caste classification to understand how agents behave as individuals and together through collective interaction. Each category has a variety of formal and informal interactions that define various social encounters within the city and have associated architectural typologies that spatially facilitate said interaction. Village typologies indicate an informal and spontaneous collection of interactions whereas student hostels indicate a formalised collective, as an example. These environments have been listed within this social analysis as a catalogue of typologies that can be instanced into the simulation output during later stages of development.

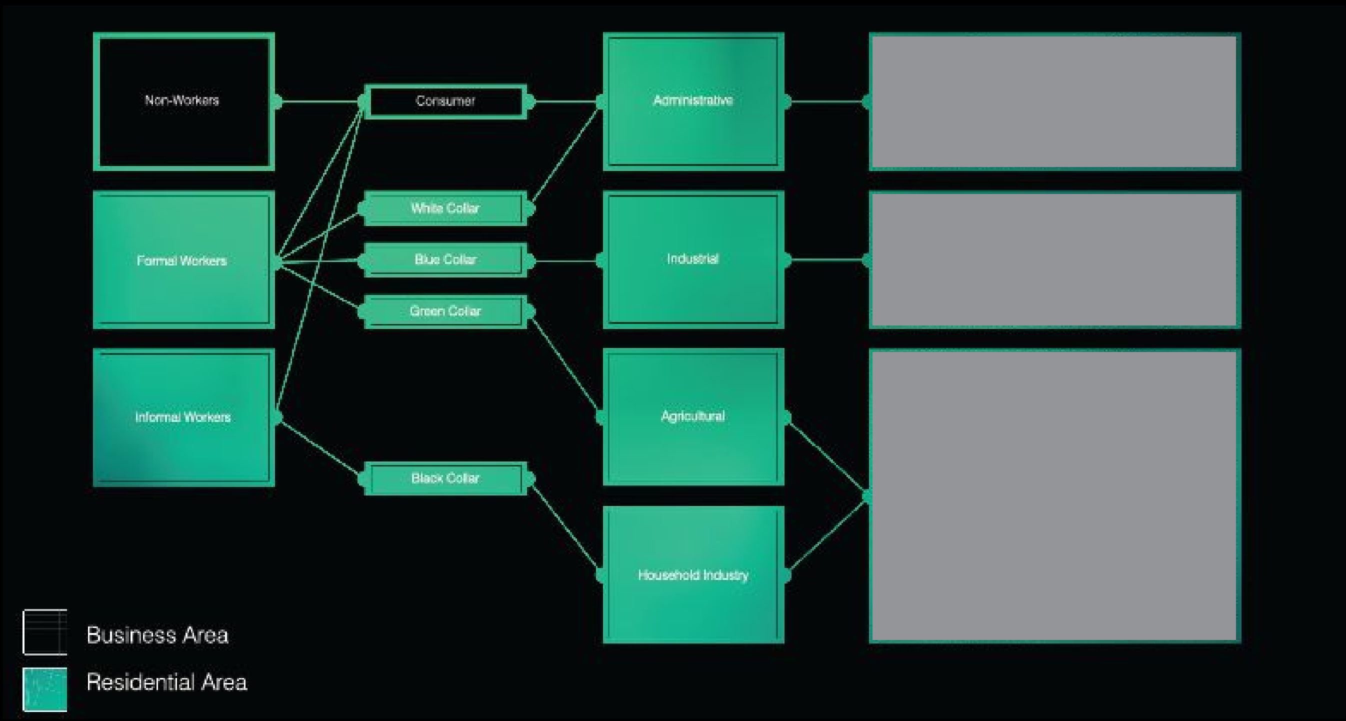


Figure 2.4: Economic Agents of New Delhi.
Identifying the various economic agents being considered within this investigation.

The economic agents of New Delhi have been analysed and broken down into two categories, working class and consumer, to understand how agents behave and interact as a collective. The working class analysis presents both formal and informal workers that operate at various scales within the city as well as generic consumers that are common within any economic climate. Informal workers are a unique type of agent specific to India's working class that operate through household industries, within a neighbourhood scale and therefore requires typologies both informal and connected to other settlements. Formal workers in contrast operate through standardised developments such as factories and office buildings and therefore interact formally. Each category has an associated formality that reflects how its agents interact within select spatial environments that have been catalogued as potential typologies that can be instanced into the final simulation output.

Context Considerations.

This segment looks to establish areas of interest within the wider context of New Delhi by identifying artefacts that can influence agent behaviour and interaction within the final simulation. These artefacts are central to the developed design as existing areas of socioeconomic interaction that can integrate with the scheme and embed the design into its context. Artefacts are identified within this segment to give insight into the wider context and catalogued into areas of interest that can be plugged into the final simulation. The following map studies indicate wider social and economic territories that have influence over agent behaviour (through proximity) and will be integrated within later developments.

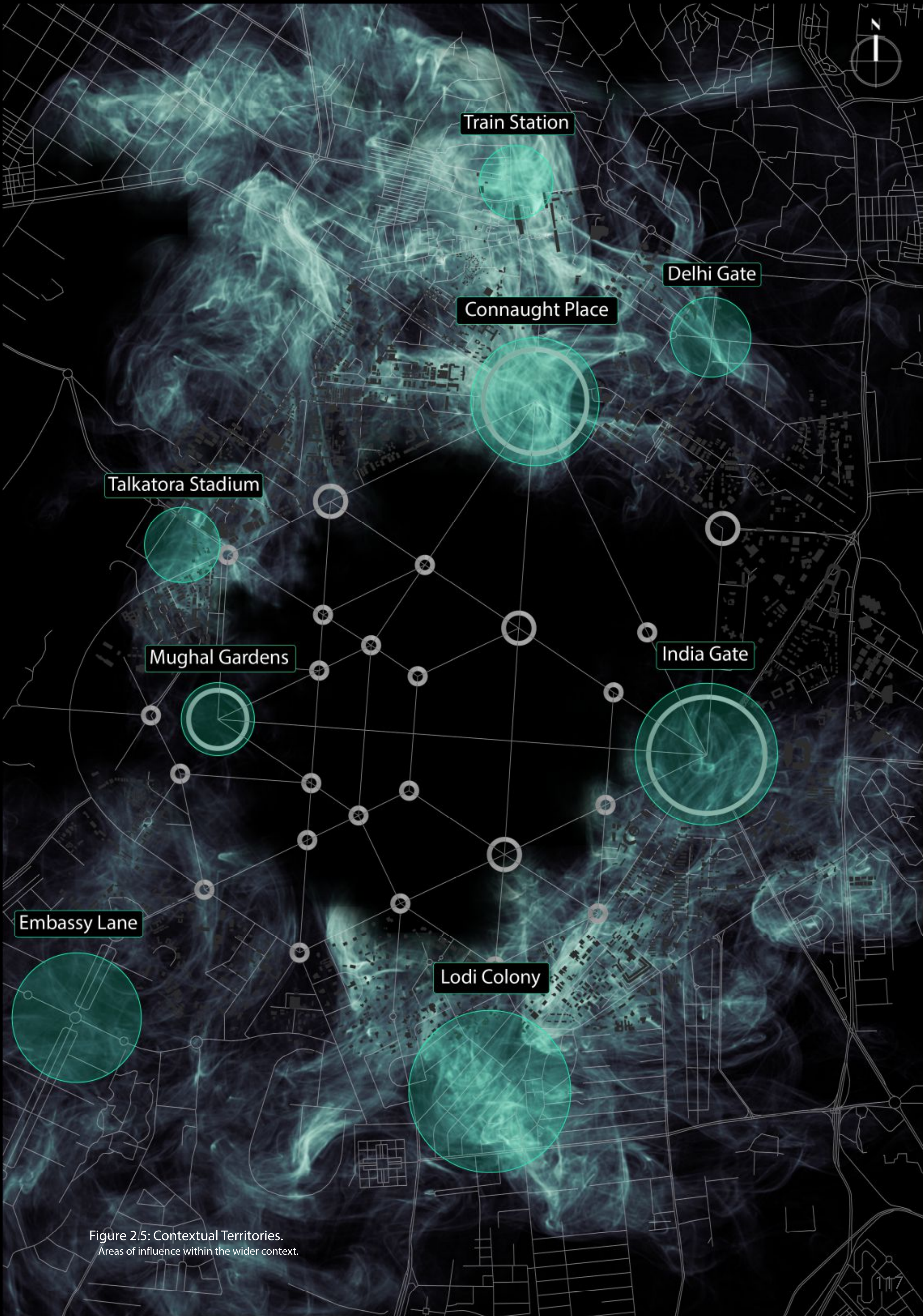


Figure 2.5: Contextual Territories.
Areas of influence within the wider context.

Final Simulation.

The final simulation amalgamates various design experiments from the preliminary design chapter to create a cohesive agent-based methodology that will inform the developed design of this research. Agents and artefacts are given agency through specified parameters and territories are created to influence the final ecology of interactions within the agent-based simulation. The final design experiment is developed using a cohesive agent-based methodology to plug in context-specific parameters, creating agent – environment interaction. The following maps show the simulation in-situ through various layers of information outlining the specific parameters used to assign agency and territory. The first map shows the final 'pre-geometry' as a swarm of particles and trails. Subsequent maps show context-specific parameters extracted from site, plugged into the simulation as artefacts and territories that affect agent behaviour through proximity. This design experiment explores the research objective and agenda of developing an agent-based methodology that is behaviour driven to inform urban design solutions that are emergent. This segment (within the chapter) highlights the emergent nature of agent-based modelling and how behaviour driven urban developments compare to traditional top-down planning of cities. The emphasis on behaviour driven output will allow this scheme to organise typologies and infrastructure into a speculative urban design that presents behaviour, interaction, artefact and emergence as modern design parameters.

Figure 2.6: Final Simulation Output.
Agent trails showing the final ecology of interaction for the context-specific simulation.

Figure 2.7: Final Simulation Output - Plan View.
Plan view of final simulation output showing agent trails.

Figure 2.8: Final Simulation Output - Input Parameters.
Identifying the various inputs which influenced agent behaviour.

Figure 2.9: Final Simulation Output - Internal Territory.
Plan view of final simulation output showing the internal territory in which the agents exist.

Figure 2.10: Final Simulation Output - External Territory.
Identifying the external socioeconomic territory that influences agent behaviour through artefacts and bleeding territory boundaries.

Pre-Geometry Development.

Pre-geometry development begins by analysing results from the final simulation output to highlight areas of increased agent interaction and areas in which large developments can exist. The following design experiments instance geometry into the simulation output, using analysis to position preliminary mass models in place. These preliminary models act as placeholders that can be substituted for specific typologies to facilitate specific interactions within an area of the urban design. The following diagrams show the sequential steps taken to arrive at an abstract representation of speculative, behaviour-driven urban design that formally prioritises interaction between New Delhi's urban population. The abstract nature of this investigation allows the use of diverse geometries that represent both formal and informal interaction between respective agent types and communicate diverse interaction through geometric variation.

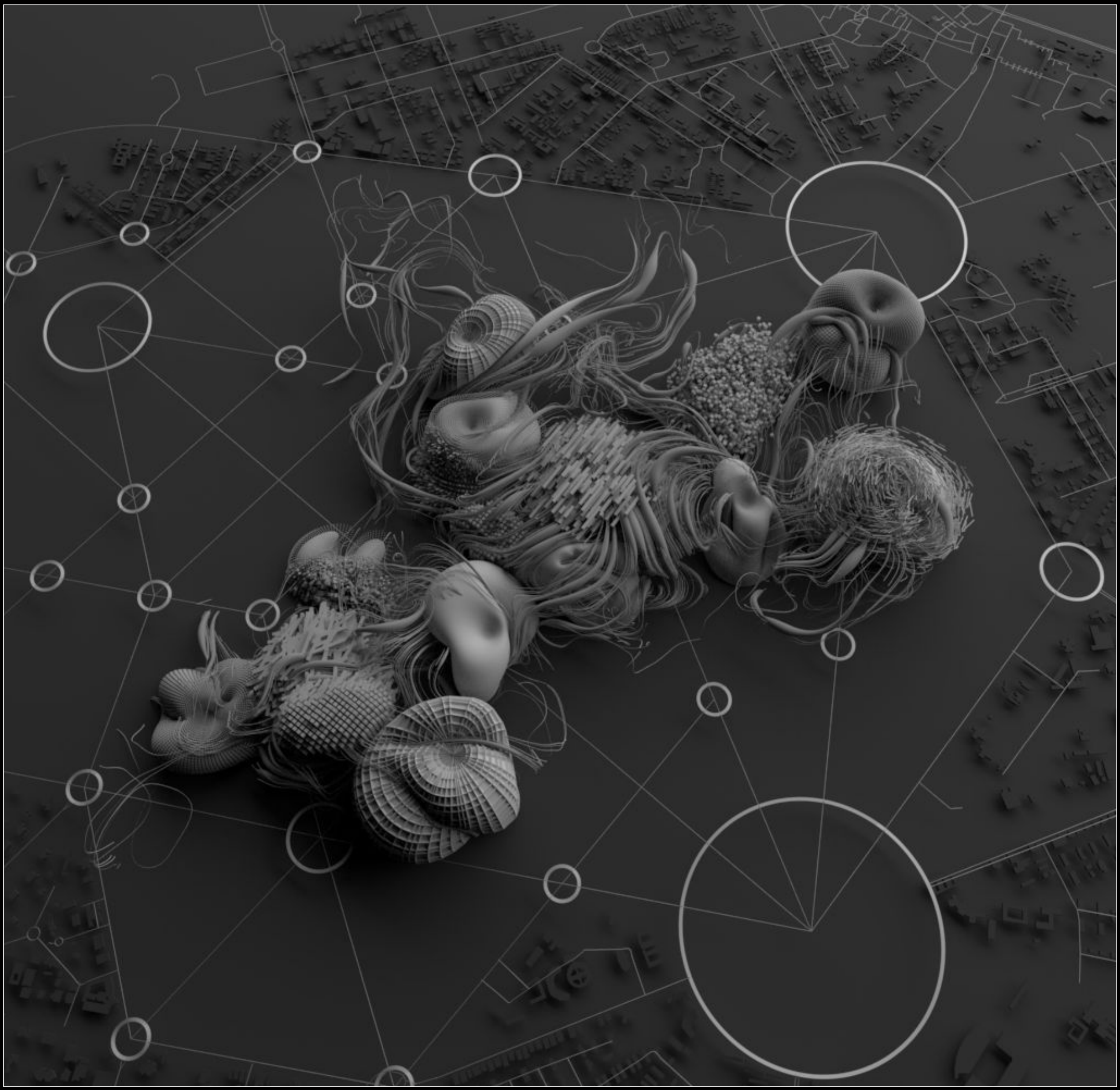


Figure 2.11: Instancing Typologies.
Birds eye view of instanced typologies within the simulation output.

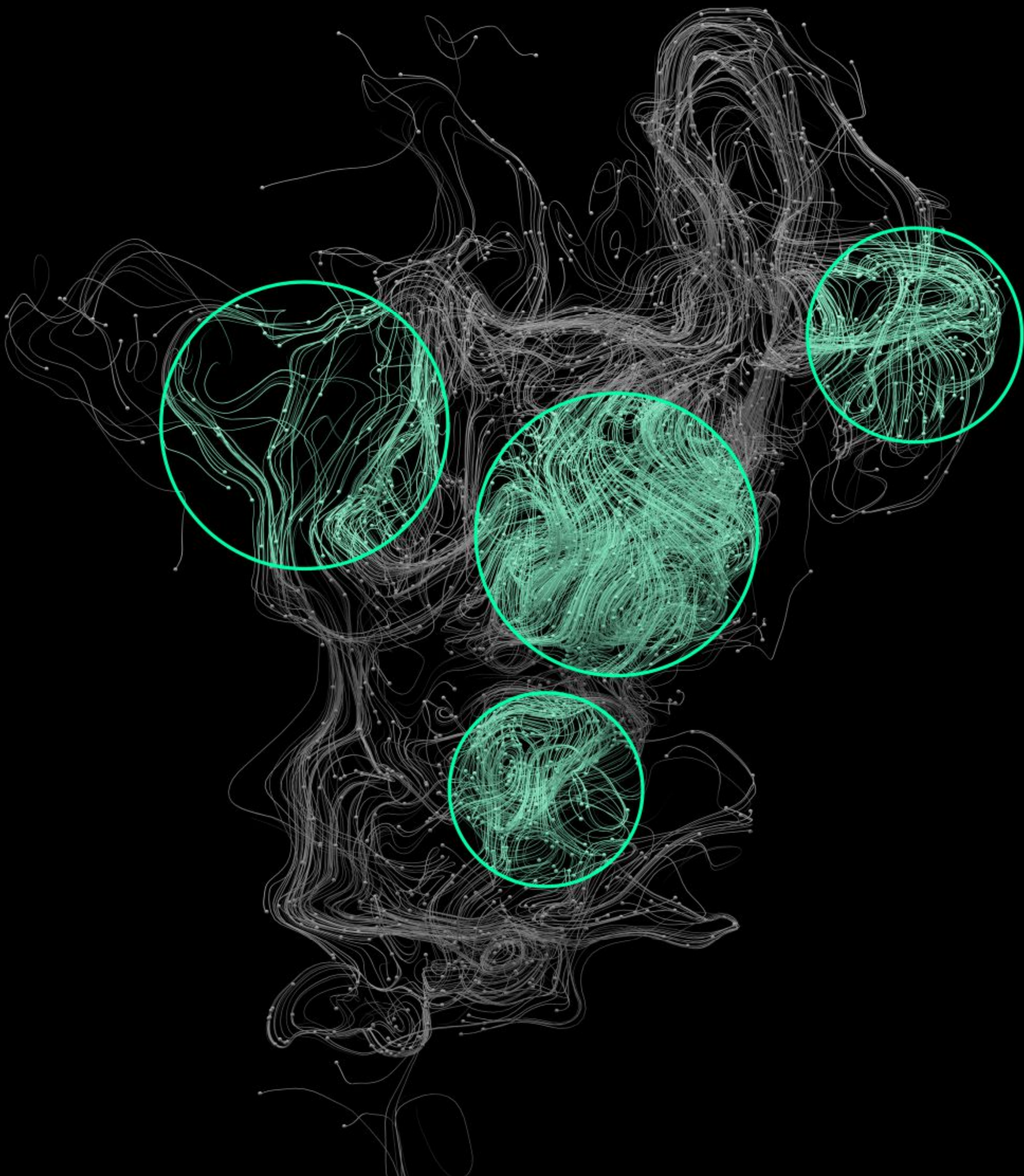


Figure 2.12: Areas of Interest.
Identifying areas in which dense interactions occur.

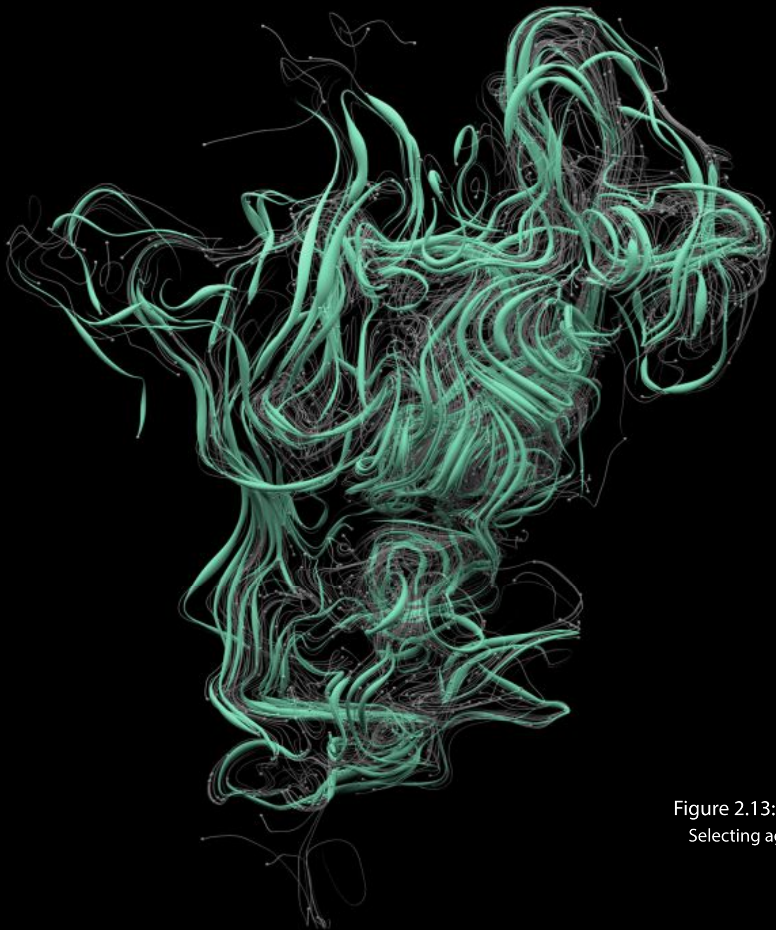


Figure 2.13: Prominent Agent Trails.
Selecting agent trails as boundaries.

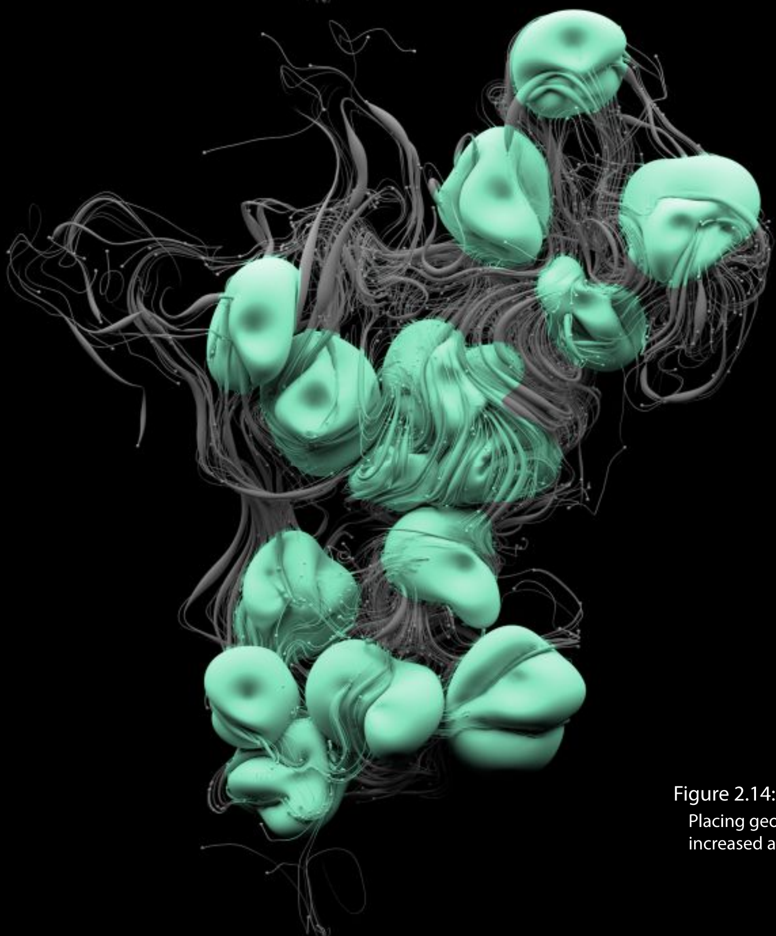


Figure 2.14: Placeholder Masses.
Placing geometry within open areas surrounded by increased agent activity.

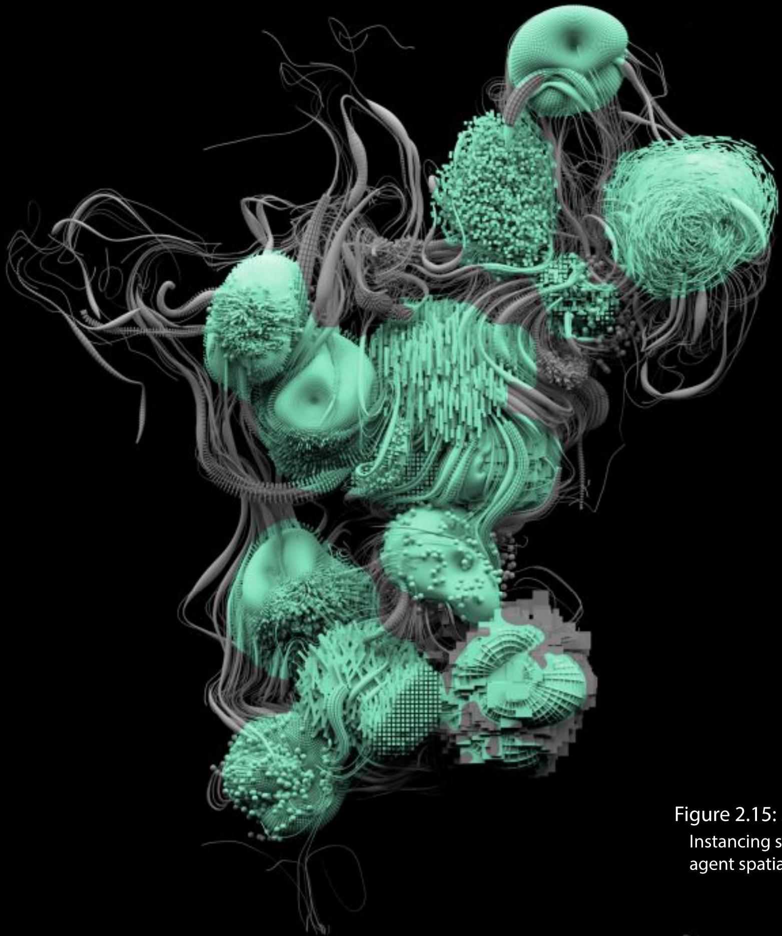


Figure 2.15: Specific Typologies.
Instancing specific typologies that correspond with agent spatial requirements.

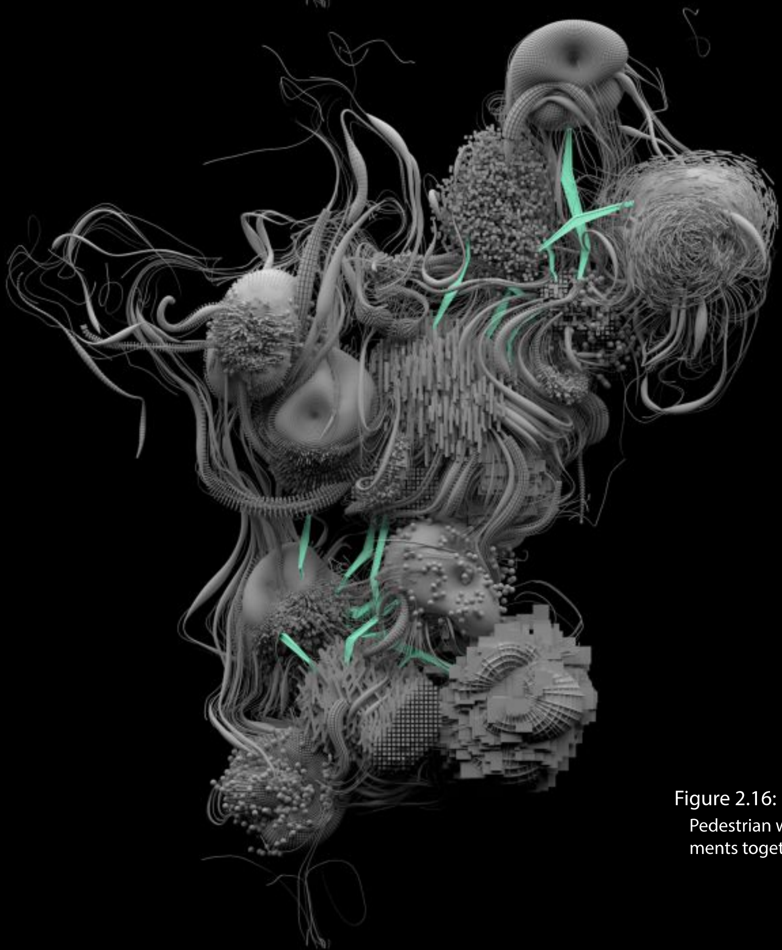


Figure 2.16: Fixed Circulation.
Pedestrian walkways connecting various developments together.

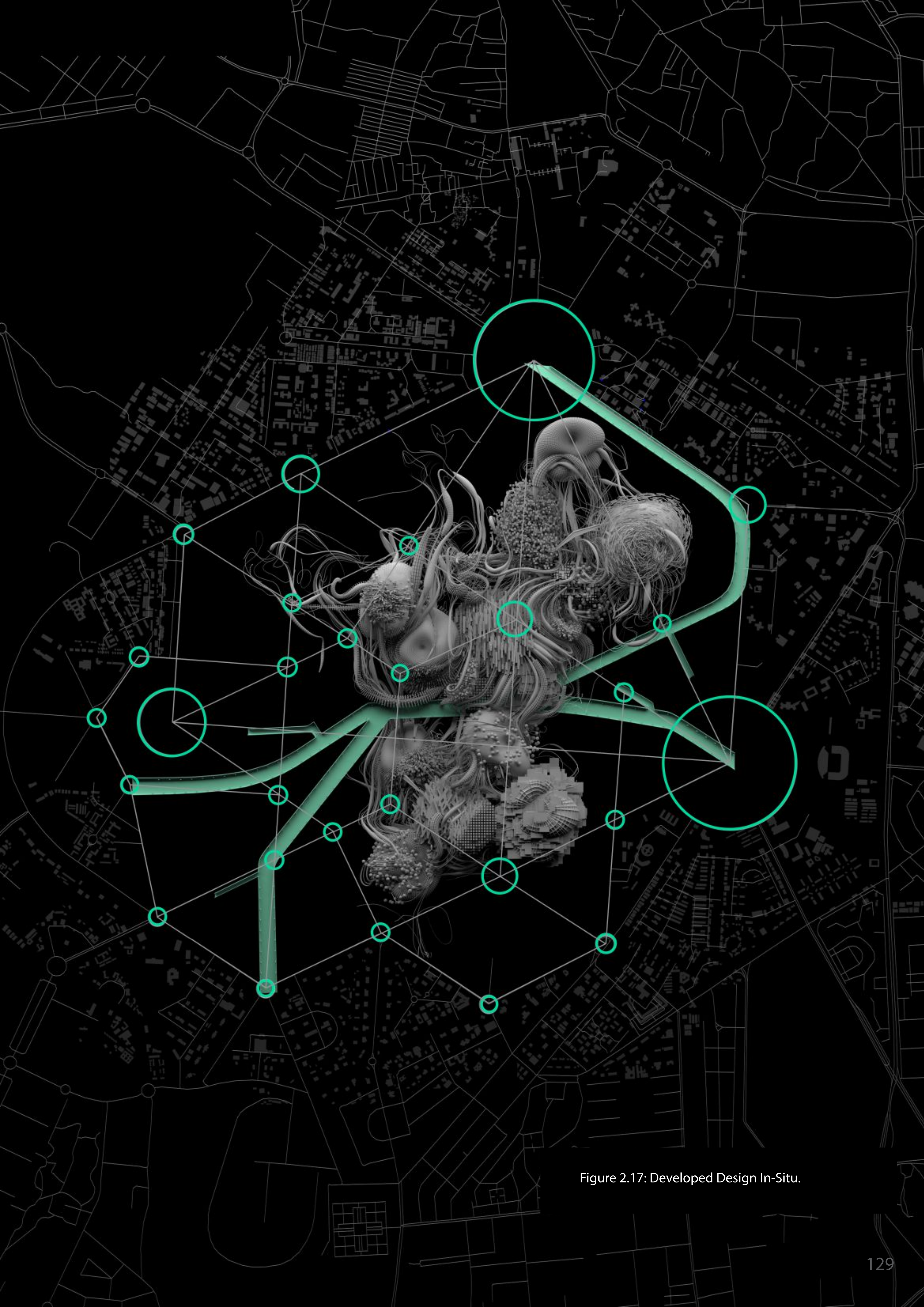


Figure 2.17: Developed Design In-Situ.

Typology Abstractions & Instancing.

Specific typologies are established within this segment to correspond with spatial requirements and various interaction types needing to be facilitated by the developed design. These requirements have been unpacked within the “Unpacking Agent Behaviour” segment and will inform the specificity of instanced typologies within this scheme. Both social and economic agents were unpacked to classify the specific spatial requirements of various agents within each category. These requirements are used to instance specific typologies within the following developed design exploration to create an abstract and speculative representation of how a behaviour-driven city could manifest itself. Each typology represents a corresponding socioeconomic interaction that is linked to its type, thereby communicating interaction through diverse and abstract geometric variation.

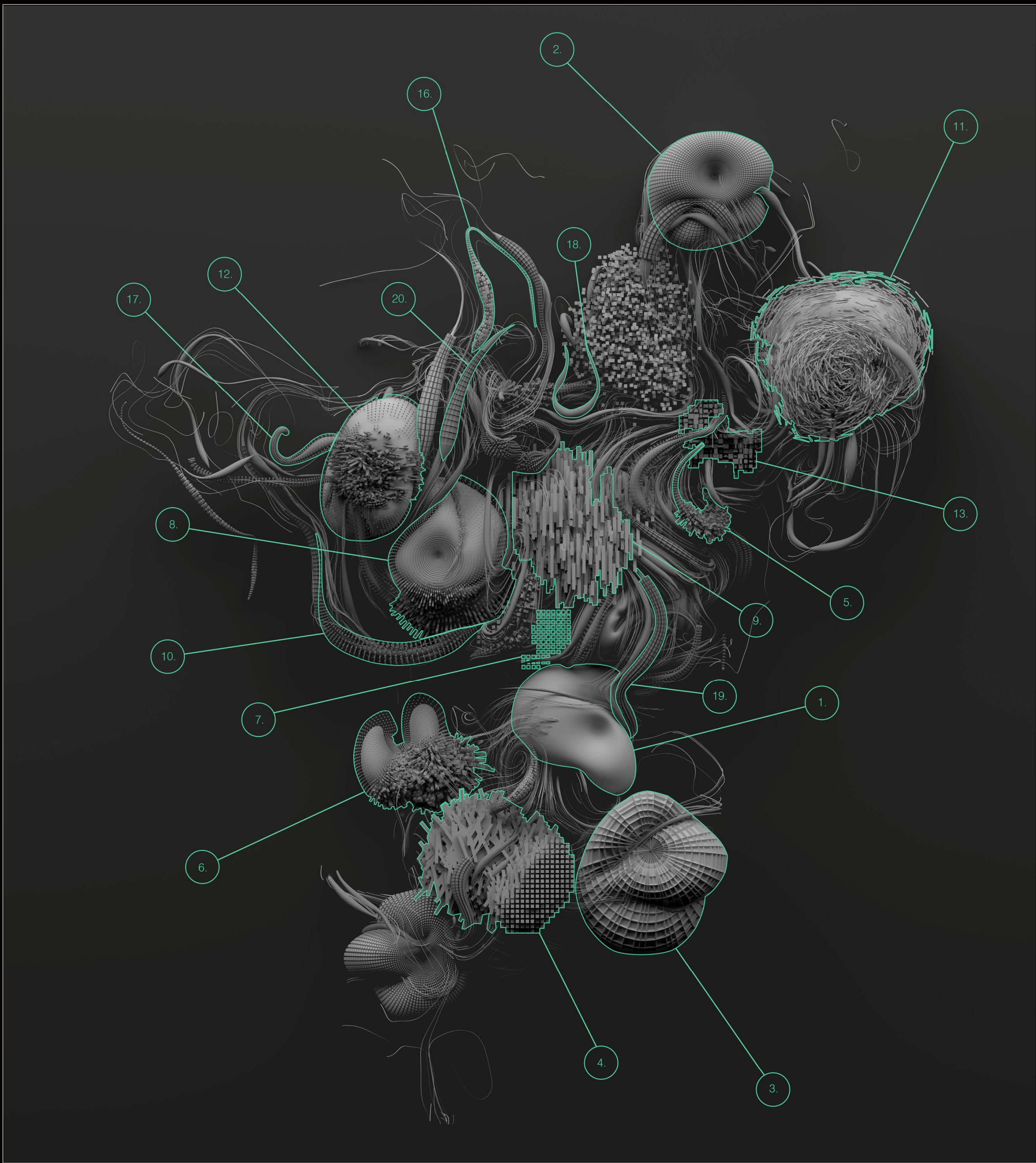
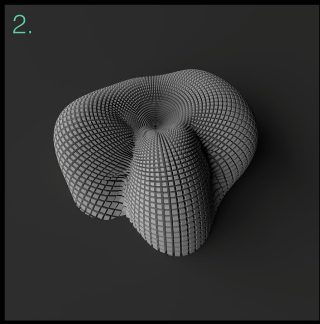
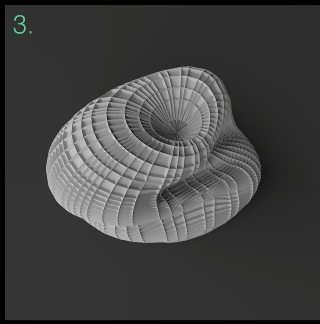


Figure 2.18: Specific Typologies - Key.
Highlighting where each specific typology exists within the scheme.

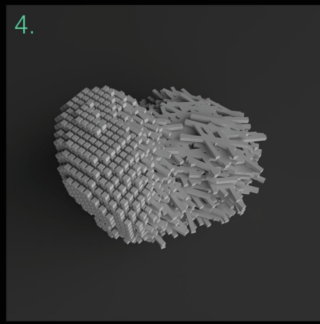
Public Area - A.



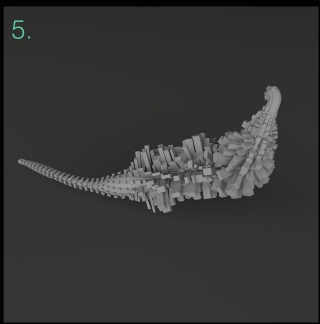
Bungalow - A.



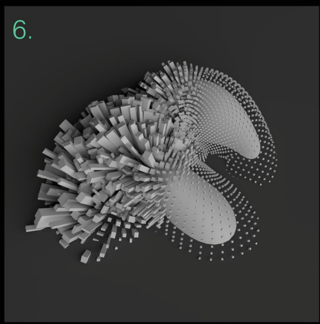
Public Area - B.



Student Hostel - A.

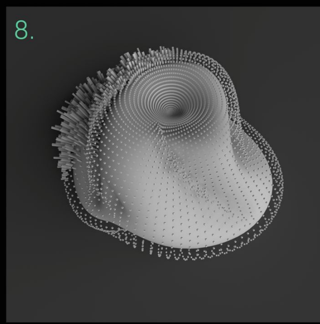


Bungalow - B.

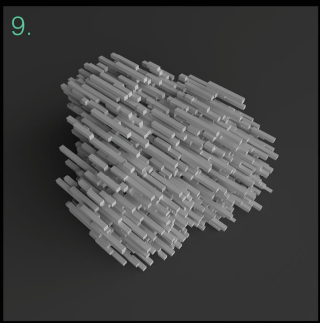


Retail/Commercial Hub - A.

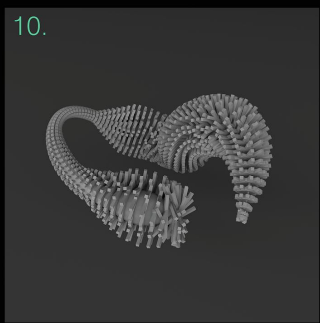
Administrative Business - A.



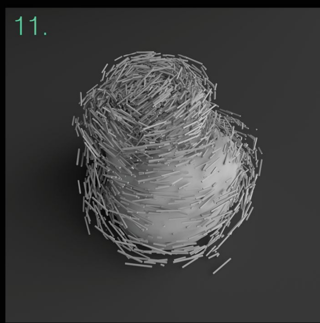
Retail/Commercial Hub - B.



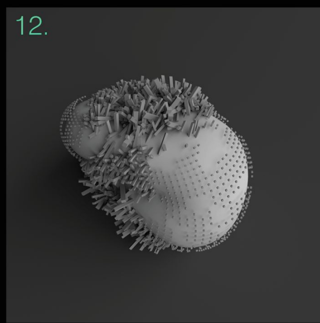
Student Hostel - B.



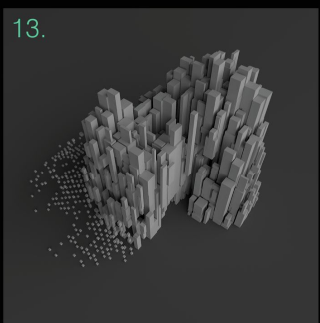
Bungalow - C.



Informal Settlements.

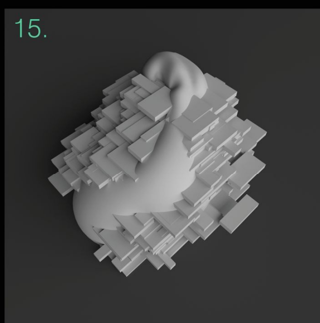


Retail/Commercial Hub - C.



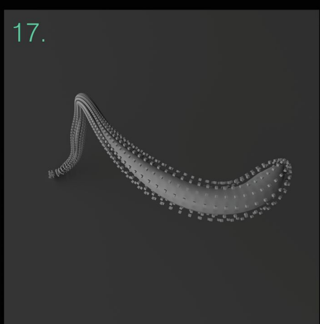
High income Apartments.

Retirement Village.

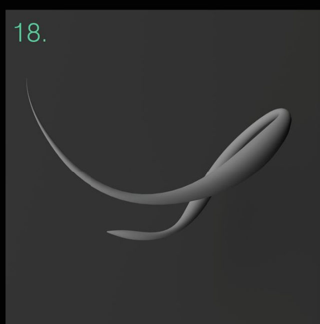


Industry/Factory - A.

Household Industry.

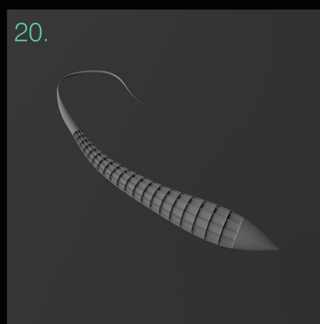


Industry/Factory - B.



Primary Circulation Paths.

Administrative Business - B.



Administrative Business - C.

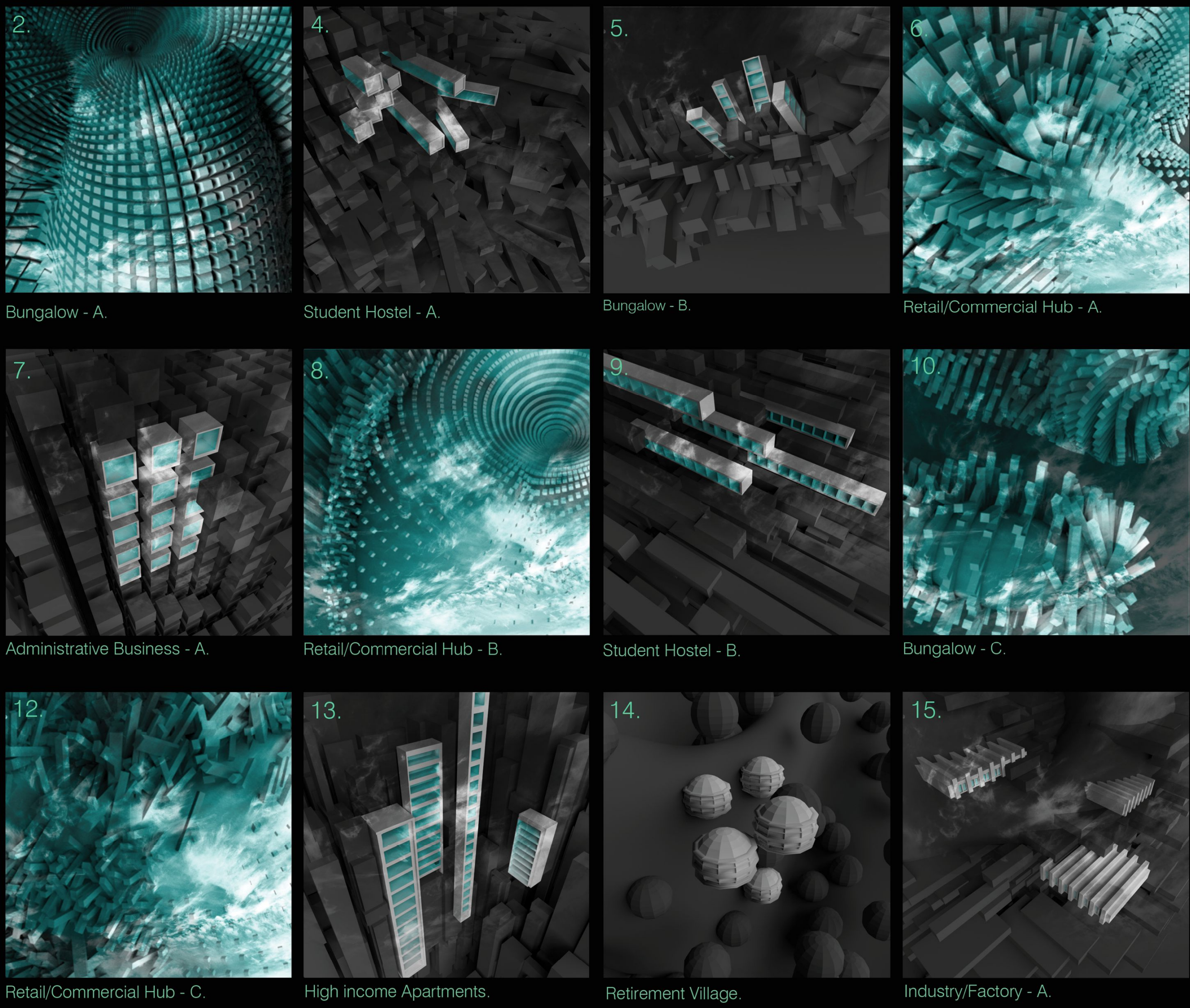


Figure 2.19: Specific Typologies - Catalogue.
Listing the various typologies that occur within the developed design.

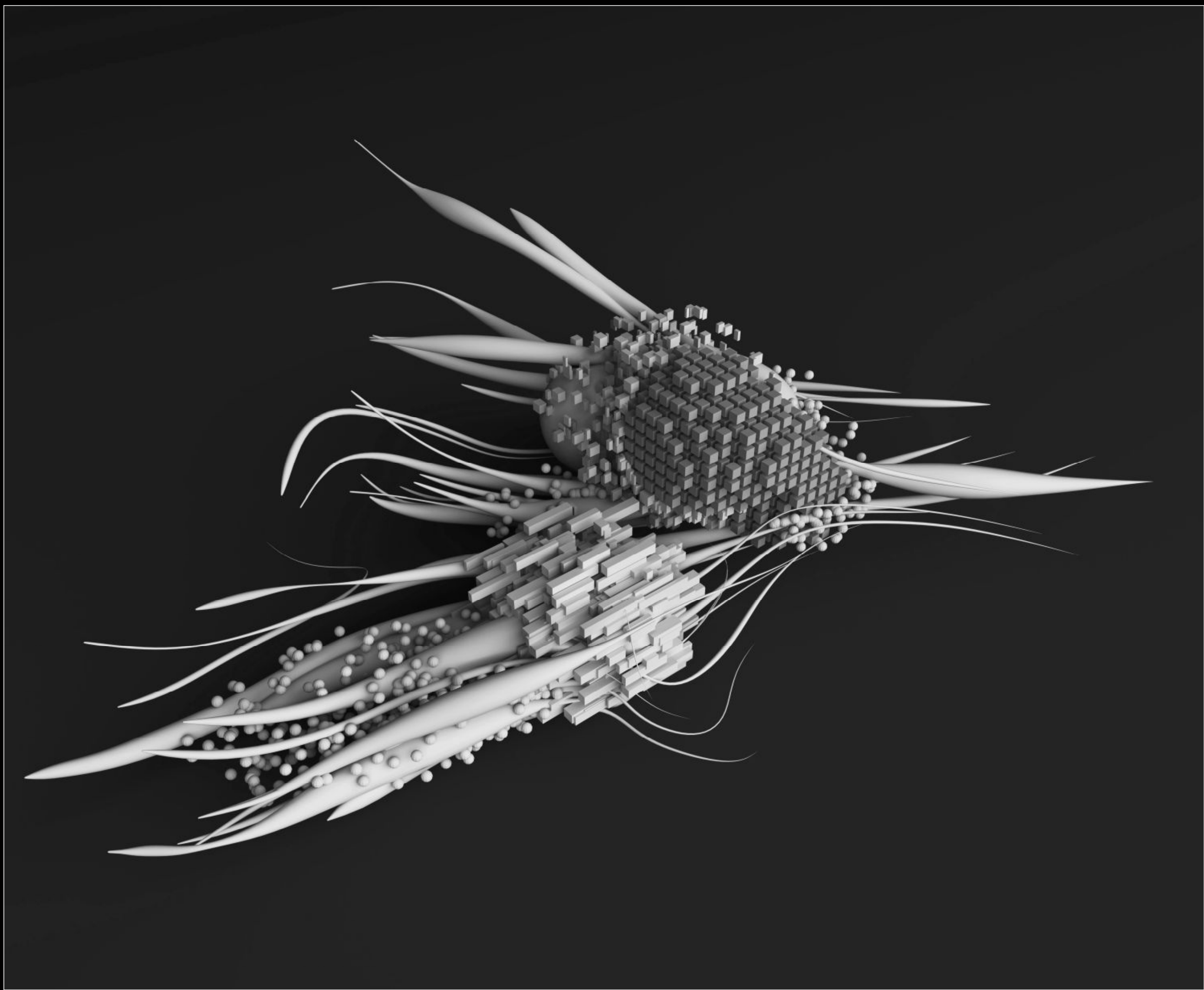


Figure 2.20: Developed Design Experiment.
Testing the capacity to organise typologies (in)formally.

Figure 2.21: Aerial Snapshot.

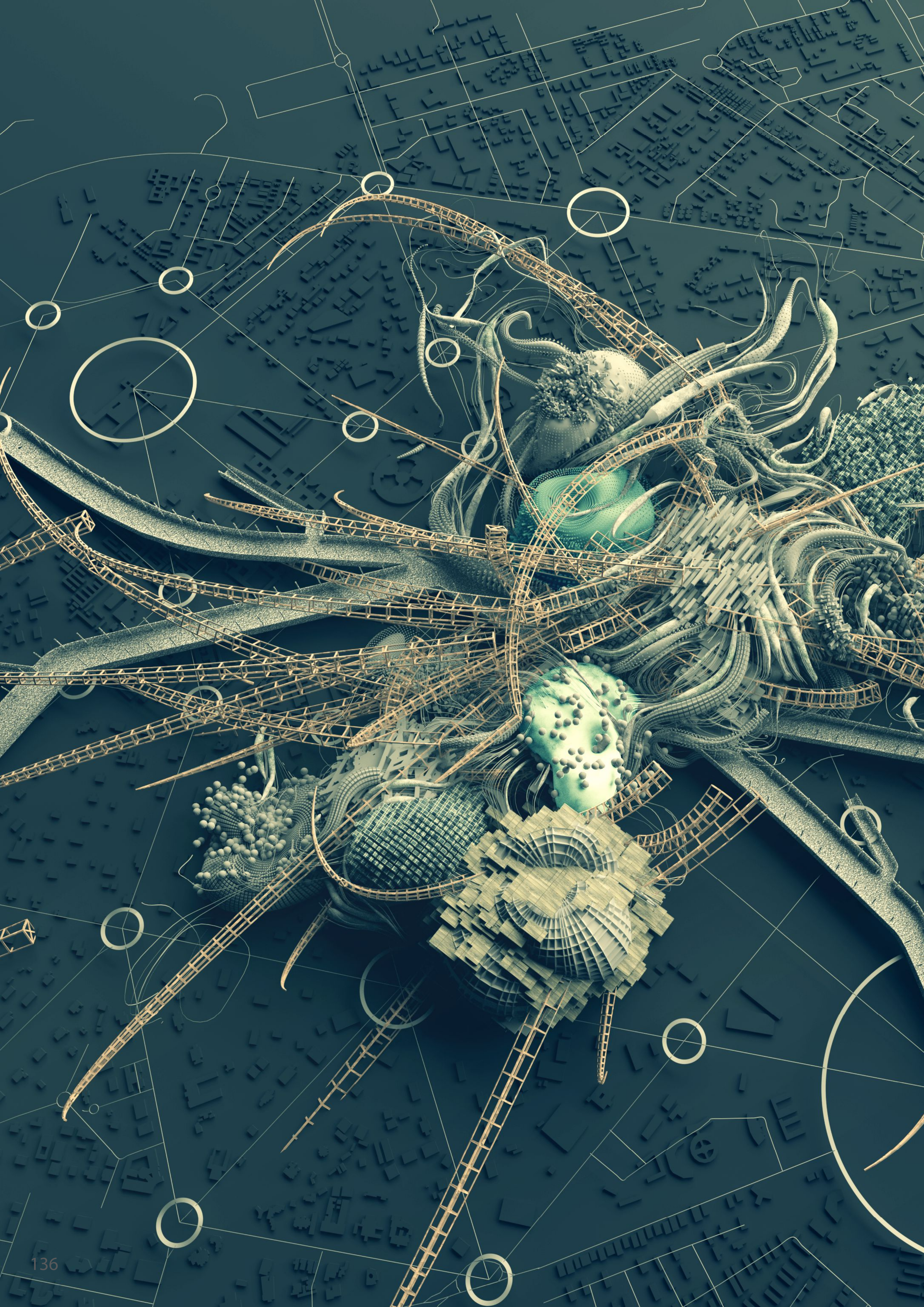
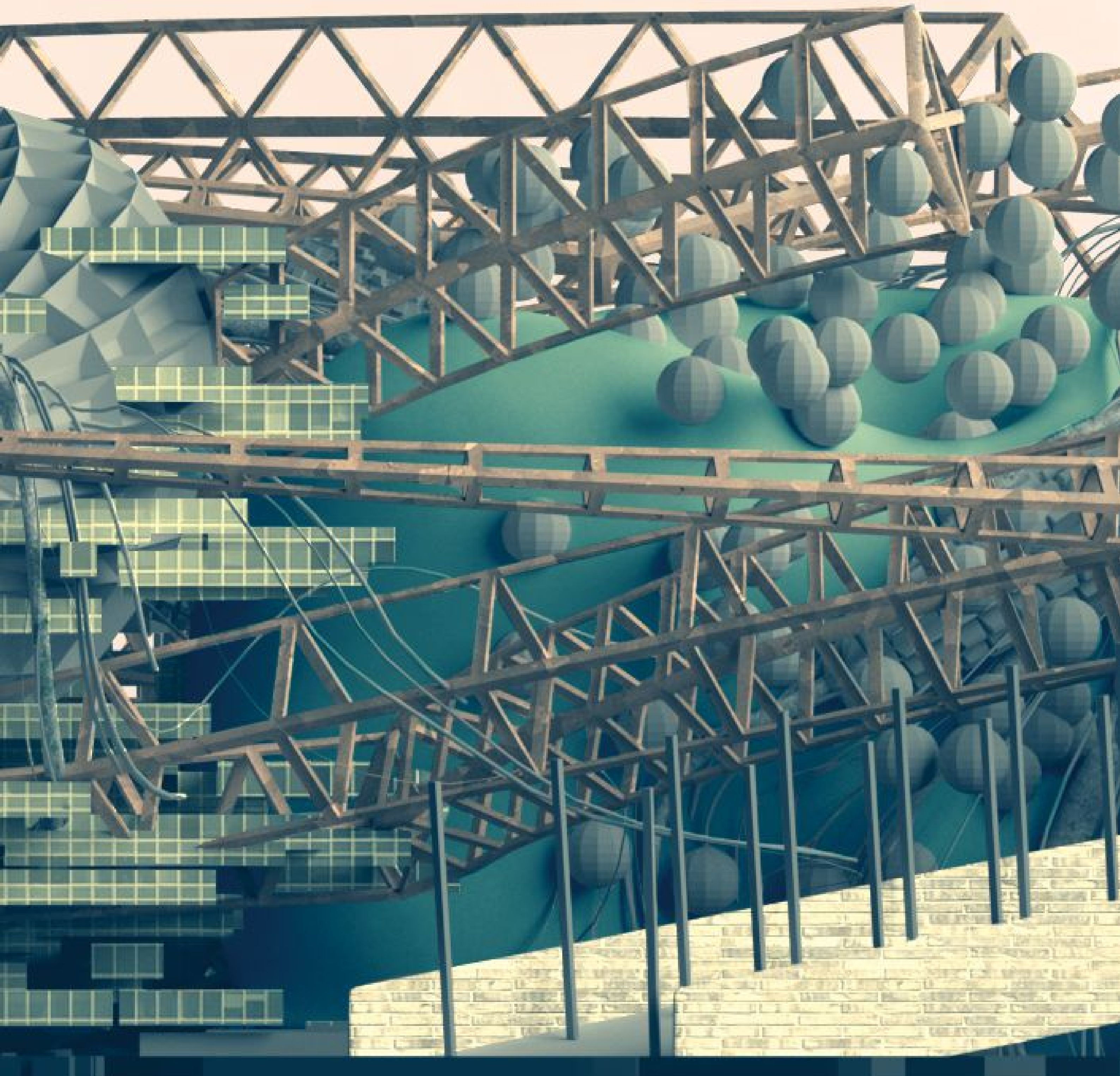


Figure 2.21: Developed Design - Aerial View.
Developed design in-situ of its context.

Figure 2.22: Developed Design - North Elevation.
North elevation showing scale of design in relation to context (pages 121 - 127).



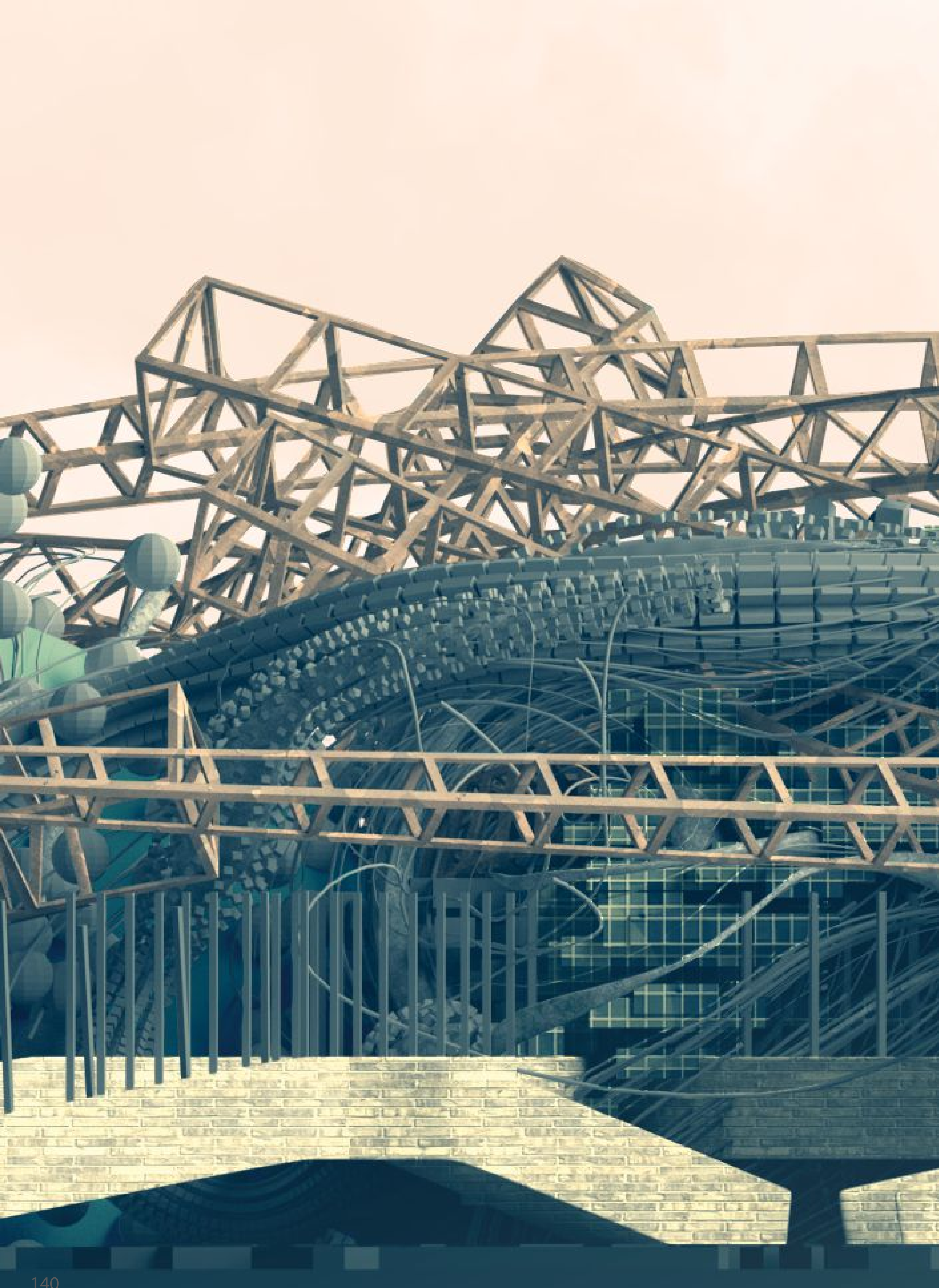
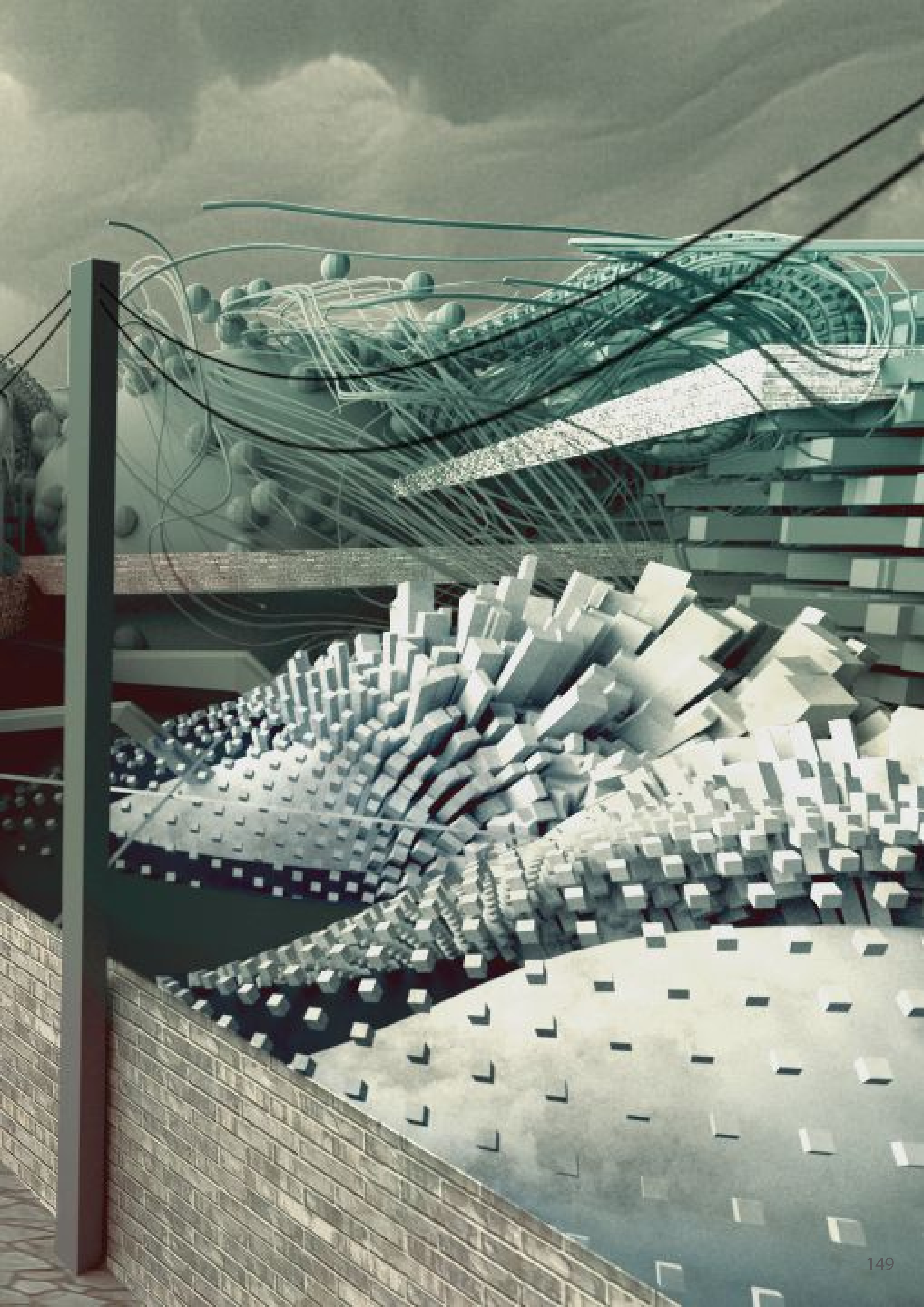


Figure 2.23: Developed Design - Perspective 1.

Figure 2.24: Developed Design - Perspective 2.



Critical Reflection.

Developing countries are facing increased pressure to urbanise in response to growing urban population numbers over the coming decades. Demand for space to work and live within an urban environment is amplified by a variety of demographics transitioning from rural to urban living in conjunction to increased birth rates within developing countries. India is a country that faces these issues over the coming decades and was selected for this reason to be the context in which the design investigation would test its research methodology. The United Nations have outlined inclusive cities as a priority for rapidly developing countries within their "New Urban Agenda," cities which stimulate diverse socioeconomic interaction(s) to create unique opportunities for various demographics to live and work how they choose.

The discipline of architecture can address this issue by prioritising social functionality via spatial legibility within urban design that responds to occupant's behavioural tendencies by communicating various interactions that they can participate within. Communication via spatial legibility is a design priority that the discipline can use to address the issue of creating inclusive cities within developing countries by analysing their population's unique behavioural tendencies and responding via spatial communication through urban design.

The speculative framework of the design investigation allowed for open-ended, quick iteration of design experiments from preliminary design all the way through to a final developed design outcome. The resulting design experiments used representation as a primary means of abstracting both New Delhi's population and subsequent typologies that would create an inclusive urban ecology, forming the final design solution. Abstract representation however has its limitations when sharing the result of design experiment's with designers outside of the design process and therefore requires explicit definitions to be assigned to each experiment as a result. The abstraction of people and typologies therefore becomes difficult to anchor within reality without explicit direction from designers involved within the process and the final solution ultimately becomes a manifestation of one designer's interpretation of design experiment's as a whole.

The responsiveness of the proposed urban design scheme towards the specific behaviour and interaction of New Delhi's demographic is reliant on the interpretation of the designer and how they assign value and meaning to various behavioural abstractions assigned within the agent-based methodology. The particular avenue of exploration within this design investigation saw abstraction of various physics-based functions being assigned as attributes of behaviour which determined how various agent types would interact with one another and with artefacts within their environment. Assignment of abstract behaviour is inherently representative and therefore requires, again, explicit definition to differentiate one behaviour and interaction type from another. This is required to help designer's outside of the process to understand the resulting design experiments, however, limits the extent to which they can interpret the results without undertaking the design investigation themselves. The particular interpretation towards responsive, behaviour driven urban design used within this particular design investigation saw the instancing of various abstract typologies into the collective interaction of agents representing New Delhi's demographic and is explicitly outlined in conjunction with the particular avenue of interpretation that myself as a design developed over various design experiments. This interpretation placed emphasis on areas of increased (dense) interaction by instancing specific typologies which spatially communicated different types of interactions that can occur within New Delhi's socioeconomic context.

Finally, the notation that "a whole is more than the sum of its parts" was an ethos that was explored within this design investigation and was inherently easy to interpret through various design experiments and the final design outcome. The agent-based methodology produced various unpredictable outcomes that expressed the underlying theoretical foundation of this research through emergence (assemblage theory in particular), producing behaviour-driven information that designers can interpret and utilise at ease. The physical data produced from these simulations and their spatial implication on design allows this methodology to be used to varying degrees of utility within various architectural projects. Interpretation between designers is less important when looking at this area of the investigation as the results of each simulation are straightforward and communicate behavioural tendencies and interaction without abstraction and explicit direction from the original designer due to its simple and straightforward representation. This area of the investigation therefore has the most to offer to the wider architectural community in terms of how the discipline can begin to address behaviour-driven, responsive spatial design at various scales of resolution.

Works Cited.

Carpo, M. (2016). Parametric Notations: The Birth of the Non-Standard. Architectural Design, 86(2), 24-29. doi:10.1002/ad.2020

DDA. (2007). Master Plan for Delhi - 2021, 312. Retrieved from https://dda.org.in/ddanew/pdf/Planning/reprint%20mpd2021.pdf

DeLanda, M. (2016). Parametrising the Social. Architectural Design, 86(2), 124-127. doi:10.1002/ad.2033

Frazer, J. (2016). History and Future. Architectural Design, 86(2), 5.

Gilles Deleuze, F. G. (1980). A Thousand Plateaus: Capitalism and Schizophrenia (B. Massumi, Trans.).

Helie, M. (2007). Emerging the City. Retrieved from Emergent Urbanism website: http://emergenturbanism.com/2007/10/18/emerging-the-city/index

Helie, M. (2009). The Journey of Emergency. Retrieved from Emergent Urbanism website: http://emergenturbanism.com/2009/03/23/the-journey-to-emergence/index

Joshi, V. (2011). Primary Census Abstract. Census of India, 16.

Lectures, E. G. S. V. (Producer). (2012). Manuel DeLanda. Assemblage Theory, Society, and Deleuze. 2011. Retrieved from https://www.youtube.com/watch?v=J-I5e7ixw78

Llabres, E., & Rico, E. (2016). Relational Urban Models: Parameters, Values and Tacit Forms of Algorithms. Architectural Design, 86(2), 84-91. doi:10.1002/ad.2028

Pioneer, T. (2018). Manoj for tweak to clause 7.4 of Delhi Master Plan 2021. Retrieved from http://www.dailypioneer.com/city/manoj-for-tweak-to-clause-74-of-delhi-master-plan-2021.html

Reynolds, C. (1987). Flocks, Herds and Schools: A Distributed Behavioral Model. Computer Graphics, 21(4), 25-34.

Roland Snooks, R. S.-S. (2009). Swarm Urbanism. Retrieved from http://www.kokkugia.com/swarm-urbanism

Schumacher, P. (2008). Parametricism - A New Global Style for Architecture and Urban Design. Architectural Design, 79(4).

Schumacher, P. (2016). Advancing Social Functionality Via Agent-Based Parametric Semiology. Architectural Design, 86(2), 108-113. doi:10.1002/ad.2031

Schumacher, P. (2016). Parametricism 2.0: Gearing Up to Impact the Global Built Environment. Architectural Design, 86(2), 8-17. doi:10.1002/ad.2018

Spyropoulos, T. (2016). Behavioural Complexity: Constructing Frameworks for Human-Machine Ecologies. Architectural Design, 86(2), 36-43. doi:10.1002/ad.2022

Wiscombe, T. (2014). The Main Museum of Los Angeles Art. Retrieved from http://projects.tomwiscombe.com/filter/featured/THE-MAIN-MUSEUM-OF-LOS-ANGELES-ART

List of Figures.

All figures are by the author unless otherwise stated.

Developed Design.