Rain Rain Go Away—Or the Dynamics of Parametric Virtual Water

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INTRODUCTION

Water is an inherently complex and enigmatic thing. It exists first and foremost as a physical thing, fluid in our immediate eyes, though more transient in its fullest material form, and certainly latent with issues both pragmatic and phenomenal. It is equally an incalculable cultural symbol, resonate with a plethora of dualities, illusions, metaphors and rituals through which we identify ourselves, consciously and unconsciously. Its impact on architecture is unquestionable and immediate, affecting the act of making with the full weight of it as an idea, and thus bearing the physical and phenomenal attributes with equal and undifferentiated merit. Yet, in the light of design pedagogy, these two aspects are not necessarily conceived through even lenses, deferring to the phenomenal as the primary critique and rendering the physical to the domain of unfortunate pragmatics. Even with the introduction of digital tools, which offer such capacities for modeling and simulation, the idea of water remains married to the senses first with the techniques following like an extra-marital affair, a debased intrusion into the polite society of design that prefers these unfortunate things are better kept behind bedroom doors. While the logic of this approach is not without merit, we ask a more direct and perhaps ordinary question of the role of water in architecture: How can the digital environment be used as an informative critique within the examination of water? Is it possible to introduce water as a dynamic condition through digital modeling beyond the visual, and thus expand the idea of water to include both its qualitative and quantitative properties?

As a preliminary study, we proposed to investigate digital simulations of rainfall on an architectural model to test the flow of runoff on the construct and its site. By virtue of the animation capabilities of 3d Max and Maya, students were asked to quantitatively evaluate the interplay of architectonics and natural phenomena in order to constructively reconsider their design propositions accordingly. Water presents itself as a particle system and a liquid, both the proverbial drop in the bucket and its accumulated solution ready to spill out, demonstrating a unique set of problems and equally rich collection of opportunities for the design student to confront. Older logics deferred to an intuitive understanding of these behaviors which are often shallow, though as our students continue to exhibit greater degrees of digital acumen, the opportunities of studying water's behavior via digital means becomes increasing ripe. Through a simple reconsideration of rainfall, we ventured into a pedagogical experiment that aspired to embrace the full richness of water as a material in architecture, albeit through the intangible means of digital modeling.

LEFT OUT IN THE RAIN

Since Laugier's primitive hut, one of the primary constituents of architecture is the sheltering of human kind from the elements. Rain in particular is a perplexing phenomenon, able to behave as a particle and as a fluid. Considering water's ability to move unexpected ways, whether by force through a joint or the gravity defying feat of capillary action between surfaces, or even upward wicking within a material itself, understanding how it operates for a student can be quite daunting. Many a great architect has been vexed by rain's stalwart insistence to enter a project in the most inopportune of places and at the most inconvenient of times. Though perhaps mythical in origin, it seems entirely plausible that Frank Lloyd Wright would suggest to a client complaining about the water leaking through the roof and onto his dining room table to simply "move the table."

Anecdotes such as these are plentiful in our profession, though they do little to advance the legitimate concerns of understanding water outside. In the creative frenzy that is the design studio environment, there is much to impart upon the student about their work, especially about the qualities of space, tectonics, structure, materiality, each of which needs to find a harmonious position with regards solving the program as well. Invariably one of the last aspects of a design solution, to be considered is exactly how environmental phenomena are to be handled. Just watch the coalescence of an environmental technology class with a studio project to see post-rationalization and consternation at their best. The concerns of water suffer from a similar dilemma in the mind of the student, who tends to default to the safe defenses of architectural poetics when confronted with a poorly considered design solution. We have all been a part of discussions such as these, either within the more secluded moments of a desk crit or the more public arena of final reviews, and they almost always follow the same script:

> "I like some of what you've done here, but I don't think you've considered the roof forms very well. For one thing, you've got the roof draining right onto the front door, do you expect everyone coming into your building to pass through this?"
> "I was thinking about something else with the entry, trying to have it speak back to my original concepts of the project, the theory that…
> "but it will be a deluge – everyone will get wet…and look at this connection…it is going to leak."
> "What do you mean? it will leak?"
> "Well look at the roof. The roof slopes towards this wall, how will you keep water from penetrating the wall?"
> "umm…Caulk?"

We are quite accustom to these chats with students, and while we can accept them coming from a young design student who's naivety about such concerns is acceptable, the recurrence of these discussions in later studios is more distressing, particularly in Central Florida where rain is a common occurrence. This may even be at the root of our decision to test a different method of study, to pursue a graphically clear means of demonstrating to our students the impact of roof and envelope design on the viability of their projects, moving beyond the simple shedding of water from a roof into an exploration of how water can be channeled across a building, retained and reused within the broader scope of their design ideas. Though there are certainly different paths available to us, we chose to use the digital realm as our laboratory, venturing into the unfamiliar territory of particle simulation.

PROCESS

One of the many paradoxes that digital tools present is the sheer number of infinite operations that are achievable with seemingly little effort. Though simple in premise, the task of digitally simulating rainfall in an accurate and measured way has proven to be remarkably challenging. Given the plethora of software that are available and their intrinsic complexities, it became immediately apparent that we would need to look far a partner with greater familiarity and programming expertise. For these reasons we forged a connection between our School and one of the University of Florida's premier interdisciplinary centers, the Digital Worlds Institute currently housed jointly in the colleges of Engineering and Fine Arts.

Realizing the institutional friction a formal collaboration might create, we began simply. Three architecture professors set aside a two-week segment within a design studio dedicated to building in the Florida landscape.[1] Our climate (semi-tropical with daily rainfall all summer) makes a study of water obvious and, in retrospect, almost essential. We posed this question to the students and faculty in an ongoing special topics research seminar taught within the Digital Worlds Institute: Can the flow of rainfall onto a building and landscape be digitally simulated in such a way that students can understand the repercussions of their designs and then work to modify their structures to more responsibly and poetically shed water?

After a series of discussions regarding software alternatives, Maya was selected as the testing platform, given its capacities to simulate gravitational behavior and impeding surfaces. With the assistance of the Digital Worlds Institute, the students were able to successfully import their virtual models into the dynamic animation environment found within Maya. Exported as .dxf files from 3D Studio Max and introduced to the Maya three-dimensional environment, the process for particle simulation was relatively simple. Maya allowed for the creation of a particle emitting source element placed above the model and a gravity element created below the model to control the direction of particle movement. This system established the preliminary condition of purely vertical particulate flow as an abstraction of individual raindrops falling. Density was modulated through a numerical system of randomly located particles emitted with an upward limit of 500 particles/second. Adjustments with particle size accounted for the approximate size of individual drops. Modulation of the particle's dynamic response to encountered surfaces allowed for an approximation of splash. Further definition within the model itself was required in order for the particles to react to the model surfaces directly. All modeled surfaces required definition as either an active (impenetrable) or inactive (penetrable) surface. An inactive surface would have no impact on the direction or rate of travel of the particles, particles simply passed through them. Active surfaces could alter both the direction and rate of descent of particles, determined by the orientation of the surface itself as well as adjustments within the friction characteristics assigned to that surface.

The product of this simulation was a short length digital animation displaying the idealized behavior of raindrops falling onto an architectural construct and landscape. Though numerically indeterminate, the animations did allow for a visual means of analysis regarding roof and site drainage within the specific limitations of this scenario. The animations clearly delineated the fundamental principles of fluid movement across varied planes that provided visual confirmation of general drainage patterns and collection points within the tectonic elements of the architecture as well as the diagrammatic conditions of site.

The process of development for this simulation

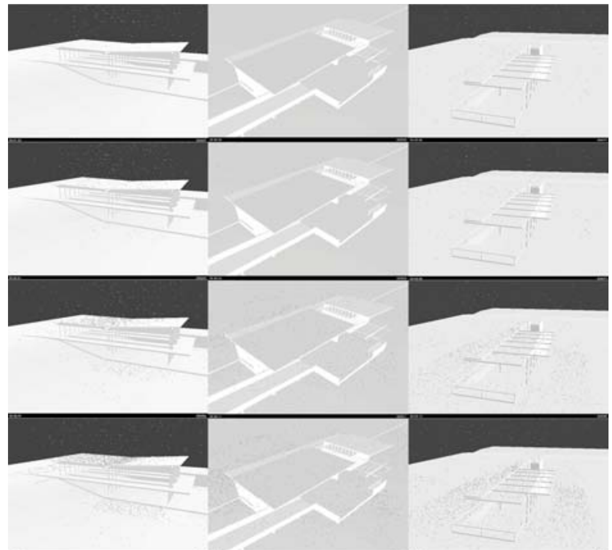

Figure 1: Captured stills from Maya by Jennifer Chue, Joe Kuehmeier, and Patrick Riddle from the fourth year D7 design studio of Professor Kim Tanzer.

prototype also revealed numerous difficulties specific to digital media, stemming primarily from software interaction. The most dominant struggle occurred with the interface between Maya and 3D Studio Max. The necessity of a plug-in for importing Max files was not initially known. Only after several days of struggle on the part of the DW was the software interface problem solved, and even then only with the addition of a secondary software element. Equally, the software interface appeared to only work with .dxf files written directly from Max. Though this was much less of a problem due to the relative ease of translation between the various modeling programs used by students, it still imposed an additional level of file translation as well as the possibility for file corruption or data loss.

Once the files were in Maya, a new set of challenges became apparent, ranging from software and hardware limitations to lack of familiarity by the user. Though the DW had been successful in projecting particles onto a surface and incurring an effective representation of gravitational flow, the behavior of the particles could not be adapted to fit the characteristics of fluid movement. The resulting simulations, though indicative of general flow patterns were more fictional at roof edges, where the particles followed a trajectory which was in fact noticeably longer in horizontal throw than would actually occur with liquid flow. Equally, the particles necessarily remained autonomous as elements, not interacting or combining with adjacent particles to form larger fluid bodies, which in turn allowed for only the suggestion of pooling water on a roof or a site. They never exhibited cohesion. While Maya 4.5 does have potential for the animation of fluid behavior, the lack of familiarity with the program effectively limited the simulation to a system of particle animation. Neither the students nor DW had enough working versatility within Maya to fully take advantage of the program's potential, let alone the possibility of innovative usage to achieve a specific type of effect.

As Maya is primarily intended as animation effect software, the computational limitations became equally apparent. Though density of rainfall could be visually adjusted, rainfall intensity was effectively limited by the size and number of emitting elements. The choice to use multiple emitting elements would have increased the file size and complexity, and applied further strain to the processing capacity of the system. At the very least it would have substantially increased animation times, if it did not crash the entire system.

The particle emission rate was qualitatively inconvertible. Any specific calibration to a more common system of notation, such as inches per hour, could not be achieved. In addition, environmental factors such as constant or gusting winds could not be explored in the allotted time. The possibility of surface distinction was equally vague. Permeability of surfaces could be implied with adjusted friction, but the particles could not penetrate the surface, only move more slowly on it.

A further compounding struggle was the hardware itself. Maya's intensive operations require a powerful CPU in both processor speed and memory. Model complexity and thus accuracy had to be kept to a minimum in order to simplify the particle simulation. In addition, once the models were imported into Maya 4.5, all operations had to be performed with this version. Preceding versions of Maya were not compatible, resulting in a reduction of the available number of viable software seats.[2]

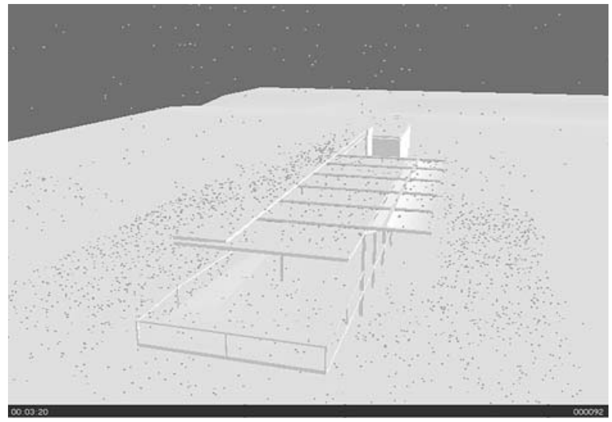

Figure 2: Designed project inserted into the particle simulation environment by Patrick Riddle from the fourth year D7 design studio of Professor Kim Tanzer.

Later experimentations involved Max exclusively instead of Maya due to the improved inter-changeability of file formats between programs.[3] At the time, this hindrance proved quite time consuming and limited the ultimate outcome. Max directly imports the students' AutoCAD model files, and allows for a more logical assignment of material characteristics than Maya. Solid objects are assigned to be Rigid Bodies so that the particle system simulating rain cannot pass through them. Max also allowed for more control over the simulated rain. The amount, direction, intensity, size, and speed of rain drips are controllable through extensive parametric settings. These options are easily adjusted for different climatic situations, so one can test rain run off for simple rain showers as well as hurricanes and snowstorms if the need arises.

One of the new challenges with the research is to make the rain particles also act with fluid characteristics when they pool together. Though not essential to the project, the inability to transform the particles to fluids became somewhat of an elusive aspiration. Even with the lifespan for the particles set to a maximum value, once the particle ceased to move and collected together they resembled a somewhat gooey mass of ping-pong balls.

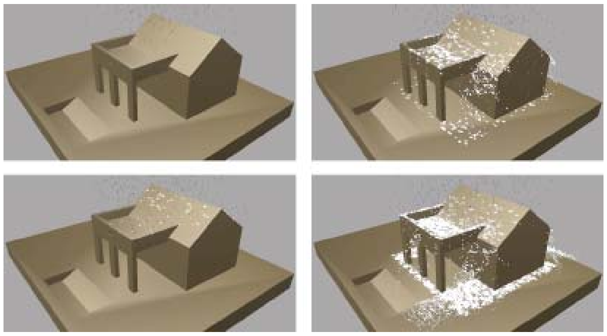

Figure 3: Second iteration of the particle simulation environment by Digital Worlds[3] student Nathan Gilder.

CONCLUSIONS

Though the experimental use of Maya seems to have been a technological success in its adaptation of the software's capabilities, the interface of the design student with the cumbersome nature of the program was somewhat debilitating. Repeated attempts of the experiment utilizing 3d Max proved a bit more fluid, but the parametric controls of particle systems still vex most students. Of course, the most digitally astute ones are able to grasp the concepts and assist their studio counterparts, but in general it is unclear as to how helpful the process is to the studio.

One outgrowth of the initial experiments was the development of a rain simulation model into which students could import their digital models in order to run the simulation without needing to manually control the parametric particle systems. They still must assign modifiers to every object within their models that is to interact with the rain particles, but this is a relatively simple if not time-consuming task. While the simulations have as such improved in providing a more efficient testing process, we have found that students rarely have a sufficiently complete digital model to test before the end of the design process, offering little time to assist in the development process.

Perhaps further utilizations of these techniques should occur at an interim period of the design process so that discoveries can be fully embraced. However, the challenge of expediting modeling process may result in very naïve, inarticulate massing models rather than coherent architectural assemblies. As long as they are allowed to develop in their tectonic and spatial languages, this may prove beneficial to the studio at large. Though cloaked by the novelties of the digital environment, our method may be no more beneficial than dumping a container of water on physical models.

As software continues to advance in the features and precision available, these types of simulations grow in relevance. The biggest obstacle at this point is the interface, so if the software becomes more transparent then students can more easily apply these techniques. Since we are committed to not teaching paperless studios, preferring a more choreographed integration of physical models and analog drawing with digital media, it will remain to be seen if the additional rain simulation is as beneficial as it is time-consuming, particularly when the students would prefer to use that time to stockpile their rhetorical defenses in preparation for our looming critique "So, you do know that your roof has drainage problems. Look here…"

ENDNOTES

1 The project was initially conceived by Professor Kim Tanzer, in collaboration with Assistant Professors John Maze and Mark McGlothlin, as a brief exercise within the fourth year design studio. To better support the digital skills of the students, the initial exercises were done in partnership with the Digital Worlds Institute of the University of Florida. The Digital Worlds Institute (DW), directed by James Oliverio, was originally intended to serve as an interdisciplinary center between computer science and fine arts, but in subsequent years this collaboration has proven quite challenging to the point that DW now exists as its own research center outside of curricular departments. This disparity between computer science and fine arts was foreshadowed in the difficulties experienced within the collaboration between the computer science students and architecture students due to very idiomatic different languages and work methodologies.

Students represented in this discussion were from the fourth year D7 design studios of Professor Tanzer and Assistant Professors Maze and McGlothlin, as well as the ART6933 graduate interdisciplinary seminar of Assistant Professor Maze and Lecturer Tressa Asselin at the University of Florida.

2 "Fluid in form and the Encoding of Space: Examining the Intersections of Architectural Design and Computer Science," Digital Architecture and Construction, ed. Ali, A. and Brebbia, C.A., (Southampton, UK: WIT Press, 2006), 11-20. Previously published in part by Maze, John, McGlothlin, Mark, Tanzer, Kim "Fluid (in)form: Influencing Design Through Dynamic Particle Simulation," Hawaii International Conference on Arts and Humanities Proceedings, (Honolulu: University of Hawaii, 2004). Available on CD-ROM. Originally published in part

by Maze, John, McGlothlin, Mark, Tanzer, Kim "Fluid (in)form: Influencing Design Through Dynamic Particle Simulation," ACADIA 2003: Connecting – Crossroads of Digital Discourse, ed. Klinger, Kevin, (Mansfield, OH: ACADIA, 2003), 354-361.

3 Maya and 3D Max are modeling, rendering, and animation programs currently owned by AutoDesk. What this means is that future experiments with these techniques will be facilitated by a more seamless integration between modeling platforms (i.e. AutoCAD, Max, Viz, Maya, Form Z, etc.) due to the exchange formats of .dxf and .dwg having been developed by AutoDesk and fully compatible with all of their 3D products.