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Intuitive Editing of Visual Appearance from Real-World Datasets

Julio Marco Ana Serrano Adrian Jarabo Belen Masia Diego Gutierrez

Universidad de Zaragoza, I3A

Abstract

Computer-generated imagery is ubiquitous, spanning fields such as games and movies, architecture, engineering, or virtual prototyping, while also helping create novel ones such as computational materials. With the increase in computational power and the improvement of acquisition techniques, there has been a paradigm shift in the field towards data-driven techniques, which has yielded an unprecedented level of realism in visual appearance. Unfortunately, this leads to a series of problems. First, there is a disconnect between the mathematical representation of the data and any meaningful parameters that humans understand; the captured data is machine-friendly, but not human-friendly. Second, the many different acquisition systems lead to heterogeneous formats and very large datasets. And third, real-world appearance functions are usually nonlinear and high-dimensional. As a result, visual appearance datasets are increasingly unfit to editing operations, which limits the creative process for scientists, engineers, artists, and practitioners in general. There is an immense gap between the complexity, realism and richness of the captured data, and the flexibility to edit such data. The current research path leads to a fragmented space of isolated solutions, each tailored to a particular dataset and problem. To define intuitive and predictable editing spaces, algorithms, and workflows, we must investigate at the theoretical, algorithmic and application levels, putting the user at the core, learning key relevant appearance features in terms humans understand.

1. Introduction

Simulation and editing of visual appearance is a fundamental aspect of digital content creation, and an inherent part of our lives as well. Our society depends on computer-generated imagery for entertainment, education, culture or architecture, while many industrial processes including manufacturing or engineering depend on correct simulations to convey the desired visual information. Moreover, developing proper design and editing algorithms for visual appearance is also a key feature for the success of novel fields at the interface between engineering, physics and graphics, such as computational materials or fabrication.

However, editing the visual appearance of computer-generated objects is a challenging goal, requiring careful modeling and adjustment of many factors, as well the complex interactions between them. Despite research efforts and the importance in society, it remains unintuitive, inefficient and very limited, even for trained practitioners. The problem is further aggravated by the current data-driven paradigm shift. Given the constant increase in computational power, together with the improvement of acquisition techniques and storage capabilities, acquiring information from the real world is becoming increasingly easy and ubiquitous [LKG*03, RK13]. This allows to reproduce the exact appearance of objects, but it leads to many limitations: first, there is a total disconnect between the mathematical representation of the captured data and any meaningful physical or perceptual parameters that humans understand, such as roughness, wetness or pliability; second, acquired data are usually large, heterogeneous, and very different between acquisition methods [DRS10], requiring specialized editing algorithms tailored to a particular dataset; and third, the high-dimensionality of the data leads to unpredictable editing results. In summary, visual appearance datasets are increasingly unfit to editing operations, limiting the creative process for scientists, engineers, artists and practitioners in general. There is an immense, widening gap between the complexity and richness of the captured real-world, visual appearance data, and the capacity to manipulate and edit it. To overcome this situation, we argue that we need to revisit the full process of modeling and editing realistic appearance, so that the data-driven approaches can seamlessly fit with intuitive spaces easily understandable by humans. We believe we need to tackle two fundamental problems. On the one hand, we need to find **human-friendly parameter spaces**, that map the intrinsic complexity of current data driven models to concepts that humans understand, building equivalent representations between the numerical representations of appearance and intuitive concepts with perceptual and semantic meaning. On the other hand, we need to find **predictable editing algorithms** based on such understandable representations of appearance, allowing a linear perceptual mapping between editing parameters and the resulting appearance, and capable of producing predictable results.

2. Early Success

Tackling the aforementioned challenges requires defining a mapping between high-dimensional non-linear functions or tabulated

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data, and a semantic (or perceptual) description of the material. This is not trivial, and requires three fundamental tasks: 1) constructing a perceptually-intuitive parameter space that is expressive enough to allow editing of the material; 2) finding some low-level representation of the material instead of working with the raw captured data, of extremely high dimensionality (implying a trade-off between generality and accuracy); and 3) we need to find the mapping between both. On an early work, we found that for filtering bidirectional texture functions (BTFs) [JWD*14], high-level perceptual attributes could be used as a guide regarding the amount of approximation that we could apply when filtering complex appearances. Moreover, these high-level attributes correlate with low-level statistics of such BTFs. While these findings were an artifact of a wider study, and therefore were not explored in full depth, they suggested that high-level attributes could be used to guide mathematical operations over complex data-driven appearances, and that a mapping between attributes and data could exist.

More recently, we pursued this path further, and presented an intuitive parameter space for controlling material appearance defined by measured BRDFs [SGM*16] for the particular context of material editing. For such effort, we first needed to build the parameter space. We first performed a series of experiments to obtain a meaningful list of semantic attributes which could describe our dataset. For each of the attributes, and for each BRDF in a large database of nearly 400 BRDFs, we obtained a series of perceptual ratings by means of a large user study in which we gather more than 56,000 answers. Then, we chose a low-dimensional representation for the BRDFs in our database, and learned a mapping—in the form of functionals, one per attribute—between this representation and the gathered perceptual ratings. We showed that these functionals form an intuitive space for editing data-driven BRDFs, resulting in new plausible reflectances exhibiting the desired properties defined by the user. Moreover, our proposed space has potential for other applications such as novel appearance similarity metrics, or reflectance gamut mapping [SSGM17].

3. Discussion

Editing real-world captured appearances is a challenging task, given the data-driven purely numerical nature of the data. This definition of appearance, while very precise and realistic, is unfortunately very difficult to edit, and even to parse by a human user. In order to build bridges between the realism of data-driven appearances and intuitive editing, we argue that we need to find intuitive, semantic, and perceptually-uniform spaces that a user can easily understand and manipulate with predictable results, and that have a direct link with low-level numerical representations of appearance. We have shown a fully-working proof-of-concept of this approach, allowing intuitive editing of data-driven BRDFs, which produces predictable and plausible results for a sparse set of measured BRDFs. While the question of whether we can extrapolate this kind of methodology to other appearances remains open and worth investigating, there is evidence that for other complex spatially-varying materials there exists a connection between low- and high-level attributes [JWD*14], while other approaches similar to ours have been used in a different context with successful results [SMD*15]. This leads us to think that this methodology will extrapolate to other complex appearances, leading to new intuitive control spaces for editing.

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