Making grammars: From computing with shapes to computing with things

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Recent interest in making and materiality spans from the humanities and social sciences to engineering, science, and design. Here, we consider making through the lens of a unique computational theory of design: shape grammars. We propose a computational theory of making based on the improvisational, perception and action approach of shape grammars and the shape algebras that support them. We modify algebras for the materials (basic elements) of shapes to define algebras for the materials of objects, or things. Then we adapt shape grammars for computing shapes to making grammars *for computing things. We give examples of making grammars and their algebras. We conclude by reframing designing and making in light of our computational theory of making.*

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The recent wave of interest in making, materiality, and material culture – the so-called 'material turn' and 'new materialism' (Coole & Frost, 2010; Dolphijn & van der Tuin, 2012) – in the social sciences and humanities has been paralleled by growing attention and research on new materials, making, and manufacturing processes in engineering, science, and design. While humanists and social scientists inquire into the subjective, embodied, situated relationships between people and material things, their engineer, scientist, and designer colleagues tend to focus on technological innovations and applications of advanced materials and fabrication devices.

We pursue a different tack in the terrain of making and material things. We consider making from a computational point of view. Our computational view intersects with some concerns above, but offers a distinct alternative to how we can think about and engage in making. Our view is rooted in computation – but computation beyond the narrow, digital kind of computation to a more general and perceptual kind in which people carry out operations with things that may only have digital approximations. In a similar vein, we consider making to be processes carried out by people to form material things. From this perspective, the kinds of making are extensive and diverse – ranging from drawing a picture on paper, to producing an image on a computer screen,

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to weaving a basket, to 3D printing a model, to machining engine parts, to constructing a building.

In developing our computational approach to making, we also consider the relationship between making and designing, the latter often understood as an intellectual or cognitive activity resulting in a plan for action or making. Our approach collapses many of the dualisms associated with designing and making that originate with Aristotle's concept of *hylomorphism*. Hylomorphism regards creation as the imposition of an idea of form (*morphe*) upon passive material or matter (*hyle*). A reincarnation of hylomorphism, perhaps better known to architects, is Alberti's distinction between designing — as a 'pre-ordering of the lines and angles conceived in the mind' (Alberti, 1986 [1755]: p. 2) — and building. The anthropologist Tim Ingold and others have argued persuasively to overturn hylomorphic thinking and replace it with an outlook that foregrounds material processes of formation, as opposed to final products as materializations of preconceived ideas (Ingold, 2010: p. 92). Our computational approach promotes this outlook.

Specifically, we look at making through the lens of a unique computational theory: shape grammars. Since their introduction over forty years ago (Stiny & Gips, 1972), shape grammars have been identified with computational design. Within the field of computational design — beginning with its early origins in computer-aided design (CAD) up to the present day — research has focused on design and designing, as the field's name implies. Accordingly, considerable research has centered on what is taken to exist in, or issue from, the mind or the intellect, as in studies of 'design thinking', 'design reasoning', and 'design cognition'. Many of the more influential studies along these lines have been presented within the pages of this journal, and the important core ideas have been brought together very neatly in a recent book by this journal's editor-in-chief, Nigel Cross (2011). Shape grammar studies, on the other hand, have tended to focus on designs and their dynamic, perceptual properties, with less speculation about the thought processes behind their production. Shape grammars have provided a compelling alternative and overlapping theory to the many theories and tools, cognition-oriented or otherwise, within the field of computational design. Here, we propose that shape grammars also offer a natural basis for a computational theory of making.

First, we review shape grammars and the shape algebras that support their improvisational, perception and action approach to computing. Second, we propose a definition of making that follows from the shape grammar approach and is also aligned with contemporary theories of making as they have been articulated in the social sciences, humanities, and elsewhere. Third, we show how shape grammars can be adapted, through our definition of making, to what we call making grammars. Specifically, we modify algebras for the materials — or stuff — of shapes (points, lines, planes, solids) to define algebras for