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Patterns of Remixes or Where Do Innovations Come from: Evidence from 3D Printing

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PATTERNS OF REMIXES OR WHERE DO INNOVATIONS COME FROM: EVIDENCE FROM 3D PRINTING

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Abstract

The conjecture that all innovations are radical new ideas is flawed. In fact, for the most part innovations are recombinations of existing concepts, that is, so-called 'remixes'. However, creators, inventors, artists, and companies are usually reluctant to disclose their sources of inspiration for fear of possible copyright infringements. As a consequence, it has traditionally been almost impossible to pin down in retrospect where innovations actually come from. In the present paper, we consider Thingiverse, the world's largest 3D printing community, to shed light on the question of how existing ideas are remixed into new ones. Thingiverse allows creators to upload, publish, and share 3D designs. In doing so, the users are encouraged to use open licenses that allow others to build upon their designs. Furthermore, they are asked to explicitly expose the original sources of their designs. We employ methods from network analysis to select, process, and visualize these remix relationships in order to create a family tree of designs. Moreover, the study analyzes patterns of remixes that explain how creators build upon existing designs. In total, we identify ten distinctive remix patterns, which contribute to our theoretical understanding of innovation phenomena and support practitioners in the establishment of structured innovation processes.

Keywords: Innovation, Remix, Open Design, Open Licenses, 3D Printing, Thingiverse.

1 Introduction

Joseph Schumpeter—the pioneer of innovation studies—already suggested that an innovation is a 'new combination' (Schumpeter, 1942). Hence, many innovations are not fundamentally new but rather recombinations of elements that already existed. 5,500 years ago, the wheel was not invented out of thin air, it was a recombination of existing solutions. Workers used sleds to move heavy cargo. In pottery round plates were used to form symmetrical objects. The combination of the two culminated in the invention of the wheel (Ideafinder, 2014). Today, recombining existing ideas into new solutions is the basis of almost all innovations. It is hardly possible to find an innovation that cannot be dissected into prior known building blocks. This also means that the rate by which an industry is able to churn out innovations heavily depends on this industry's ability to come up with new combinations. It is therefore crucial to advance our understanding of how existing concepts can be recombined into new solutions (Salter and Alexy, 2014).

Yet, our knowledge of exactly this process remains limited. Recombinations or remixes oftentimes borrow from materials that underlie intellectual property protection. Therefore, designers, creators and firms are incentivized to conceal the original sources or to downplay their importance. This situation makes it extraordinarily complicated to pin down the original building blocks of new creations. At the same time, understanding the reconstruction patterns that transform existing ideas into new solutions would help us to develop better innovation processes and would in turn speed up innovation cycles. It is therefore highly desirable to gain a better understanding of how existing ideas can be remixed into new solutions.

To understand this process we needed to find an industry that allowed us to study which building blocks make up a certain product. Consumer 3D printing offers just that. The 3D printing community ‘Thingiverse’ encourages its users to make their designs available under an open licence. Further, the community prompts users to ‘remix’ existing designs (Cheliotis and Yew, 2009; Mota, 2011). In this case the platform shows the original designs which a new object is remixed from. This situation allows us to study in detail how remixes come to life and advances our understanding of how we can recombine existing ideas into something new. In this study we identify ten distinctive remix patterns. We find that even the most complex inheritance of ideas can be represented with these ten patterns.

The remainder of this article is structured as follows: Section 2 presents the theoretical background. Here we explain the concept of a remix in more detail and provide examples from various fields. Afterwards, we introduce our methodology and present Thingiverse, the platform that we used to gather our data. This is followed by Section 3 where we introduce the ten basic patterns of remixes and explain them in short. The article concludes with a discussion that includes implications for theory and practice as well as the next steps we are planning to undertake. The entire article is a snapshot of our work in progress and we invite anyone to provide feedback.

2 Theoretical Background

The paradigm that new innovations originate from combining existing knowledge has been at the heart of innovation management for a long time (Schumpeter, 1942; Salter and Alexy, 2014). Nelson and Winter (1982) for instance note: “the creation of any sort of novelty in art, science, or practical life—consists to a substantial extent of a recombination of conceptual and physical materials that were previously in existence.” Much research is driven by the desire to better understand how this process works and to do so several sub-fields emerged, which fall under the umbrella term ‘sources of innovation’. On the *individual level* this has been studied in the field of creativity. We know or instance that prior knowledge can enable innovative thinking as it allows individuals to transform concepts from one field to another. Though, prior knowledge can also inhibit creativity as people tend to become trapped in the existing logic (Frensch and Sternberg, 1989). Fleming (2001) points out that innovators, which are members of two distinct knowledge domains make use of that by combining previously disparate elements. On a *group level* team composition has been studied broadly. Rochford and Rudelius (1992) for instance show that innovation teams that are composed of people from diverse backgrounds have several advantages over teams from the same background. This finding has later been supported (Song et al., 1998; Paulus and Nijstad, 2003; Bassett-Jones, 2005). Tushman (1977) initiated a research stream on boundary spanning that is concerned with the innovation team’s ability to collect information and resources from within and outside the organizations boundaries. Scouting activities in order to find diverse sources of innovations have been shown to be beneficial to new product development (Ancona and Caldwell, 1992). More recent research further highlights that teams, which increase the number of search sources are more likely to come up with novel combinations (Li et al., 2013). On an *organizational level* much research has been devoted to better understand how firms can combine knowledge sources. Important research streams here are: Open Innovation (Chesbrough

2003), which studies how firms can open up to integrate outsiders into their innovation processes, Innovation Networks (Powell et al. 1996), which studies how firms form strategic linkages to other researching entities to cross pollinate one another and Technology Transfer (Bozeman 2000), which studies how finding for research can be adopted in innovation processes. Lastly, with the emergence of the *Internet* research has been carried out to understand how the recombination process can take place online. Yu and Nickerson (2011) for instance show that combining existing ideas plays a prominent role in crowd creativity. Jeppesen and Lakhani (2010) show that new solutions in crowdsourcing challenges are positively related to an increasing distance between the solver's field of knowledge and the knowledge domain of the problem. In other words, solutions are getting better if solvers can bring a new perspective to the table on condition that they are still able to understand the problem.

3 Methodology and Data Source

Thingiverse is the largest and by far the most popular community for 3D printable design files. The platform allows users to browse, upload, and remix 3D digital blueprints. What is technically a 'computer-aided design' (CAD) file is usually just referred to as 'Thing' to reflect the linkage between the digital model and the producable physical object it embodies. By the end of October 2014, more than 200,000 Things were available on Thingiverse.

Thingiverse motivates its users to put their creations under an open license because "everyone should be encouraged to create and remix 3D things" (MakerBot Industries, 2014). Open licenses allow authors and designers to share their work for further (re-)use (Cheliotis et al., 2008; Cheliotis and Yew, 2009). In the context of our analysis, this is particularly useful as Thingiverse allows us to observe the emergence, enhancement, and (re-)combination of ideas. When users upload a new Thing, they provide an insight to their creative act by indicating Things, which they used and remixed to design their own. Therefore, we are able to examine the direct ancestors as well as immediate descendants of all Things.

For this exploratory field research approach, we conducted a content analysis on publicly available internet data. The data is based on actual user activity and therefore is not prone to response rate bias (Edelman, 2012) or desirability effects (Ganster et al., 1983). To analyse and explore the collected set of Things we use tools and techniques of network analysis. The investigated data has been collected from the presented platform, where each Thing has its own profile page. A Thing's profile page contains metadata like the Things's name, the name of its creator, and numerical data (e.g., the number of views, downloads, or comments). See Figure 1 for example.[1] The cornerstone of this study is the genealogical relationship of Things with one another. This can be reconstructed from a Thing's 'Remixed From' list that indicates a Thing's immediate predecessors.

For our analysis, we map these remix relationships into a directed graph consisting of vertices (circles) representing Things and edges (arrows) representing 'remixed into' relationships between them (see Figure 1).

[1] Blockbot V3.1 by msruggles; www.thingiverse.com/thing:26833

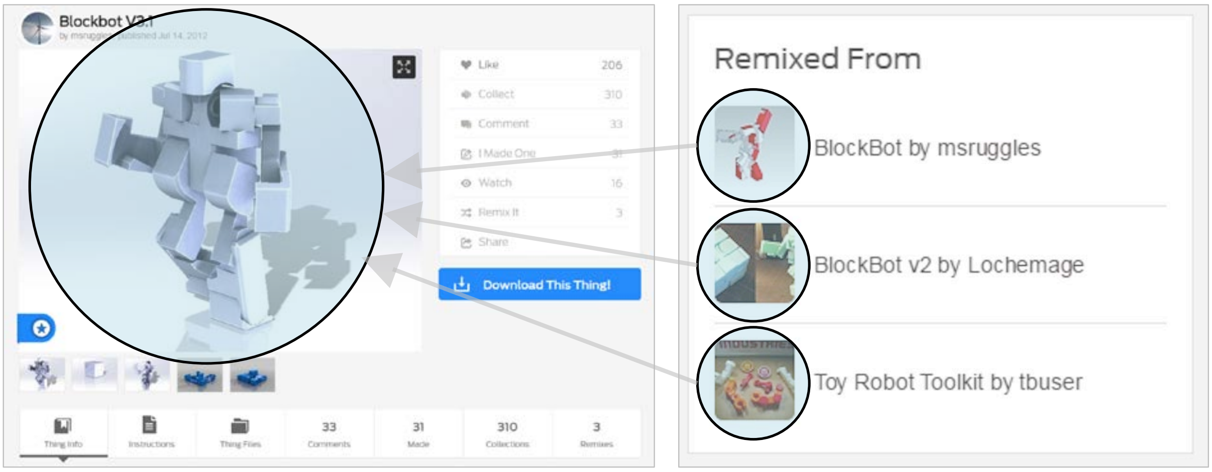

Figure 1. A Thing's profile page containing various metadata as well as ancestors of a Thing in the 'Remixed From' section.

In our preliminary analysis we narrowed the data set to contain only Things that have been published from the beginning of the platform in 2008 until the end of 2013. This sample consists of 102.299 publicly available Things. Furthermore, for the purpose of illustration, we only examined the relationship of Things that are assigned to the category 'Toys & Games'. This category has been chosen as it contains a wide variety of Things and is very popular among users. Moreover, the Things in this category, especially the corresponding remixes and relationships between them, are easily comprehensible in contrast to more technical categories such as '3D Printing'.

Another noteworthy aspect are customizer models. Such customizable Things are models that can be adapted easily within Thingiverse itself. An example of a customizable Thing in the 'Toys & Games' category would be the 'Scrabble tile generator' that allows users to customize the inscription of a scrabble tile as can be seen in Figure 2.[2]

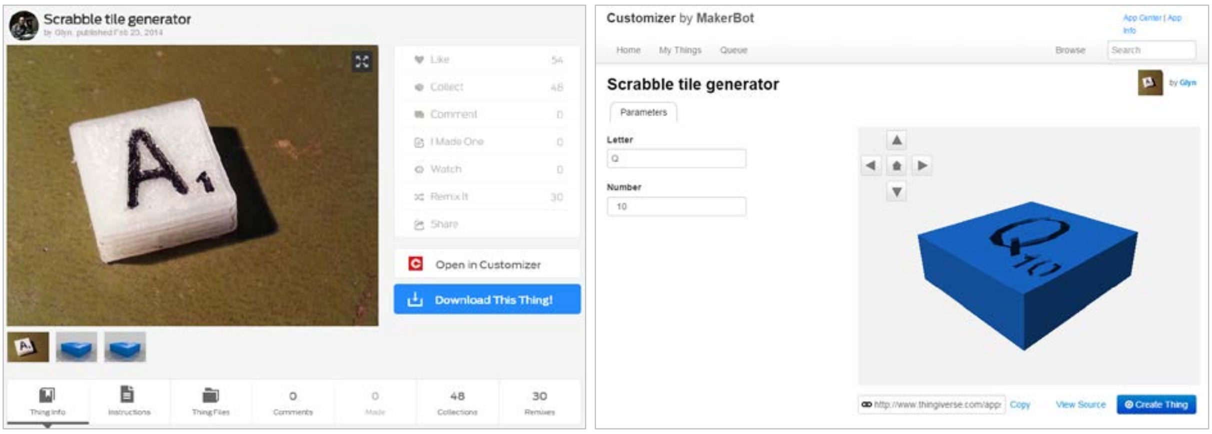

Figure 2. A 'Customizer' is a particularly designed model that can easily be adapted within the corresponding website.

[2] Scrabble tile generator by Glyn; www.thingiverse.com/thing:256248

For preparing, processing, and plotting our data we used the statistical software environment R (Adler, 2012; Field et al., 2012).[3] In combination with the open source network analysis package igraph we were able to extract and illustrate the relationships between Things in form of a graph (Csardi and Nepusz 2006; Kolaczyk and Csárdi 2014).[4] We applied the Fruchterman-Reingold Algorithm (Fruchterman and Reingold, 1991) to generate the graph in reasonable time and to meet aesthetic criteria like an even distribution of vertices and a minimization of crossing edges.

4 Results

Figure 3 illustrates the generated graph that represents the family tree of Thingiverse's 'Toys & Games' category. Each of the about 2500 Thing is represented by a vertex. The size of each vertex indicates the number of downloads a Thing received: a dot means few downloads and a large circle represents many. An edge drawn from one Thing to another indicates that the origin was remixed to create the descendant. Any Thing can spawn several remixes and any remix can borrow from several Things. The color of Thing nodes and outgoing edges indicates whether this Thing is of regular nature (blue) or whether it is customizable (orange).

The family tree in Figure 3 illustrates the subset of Things that either are themselves a remix or spawned one. All uploaded creations that show no relationship to other Things (i.e. singleton subgraphs) were omitted. Figure 3 also shows several independent subgraphs that are not connected to one another. We refer to these subgraphs as 'innovation families'.

[3] R - Project for Statistical Computing; http://www.r-project.org/

[4] igraph - network analysis package; http://igraph.org/

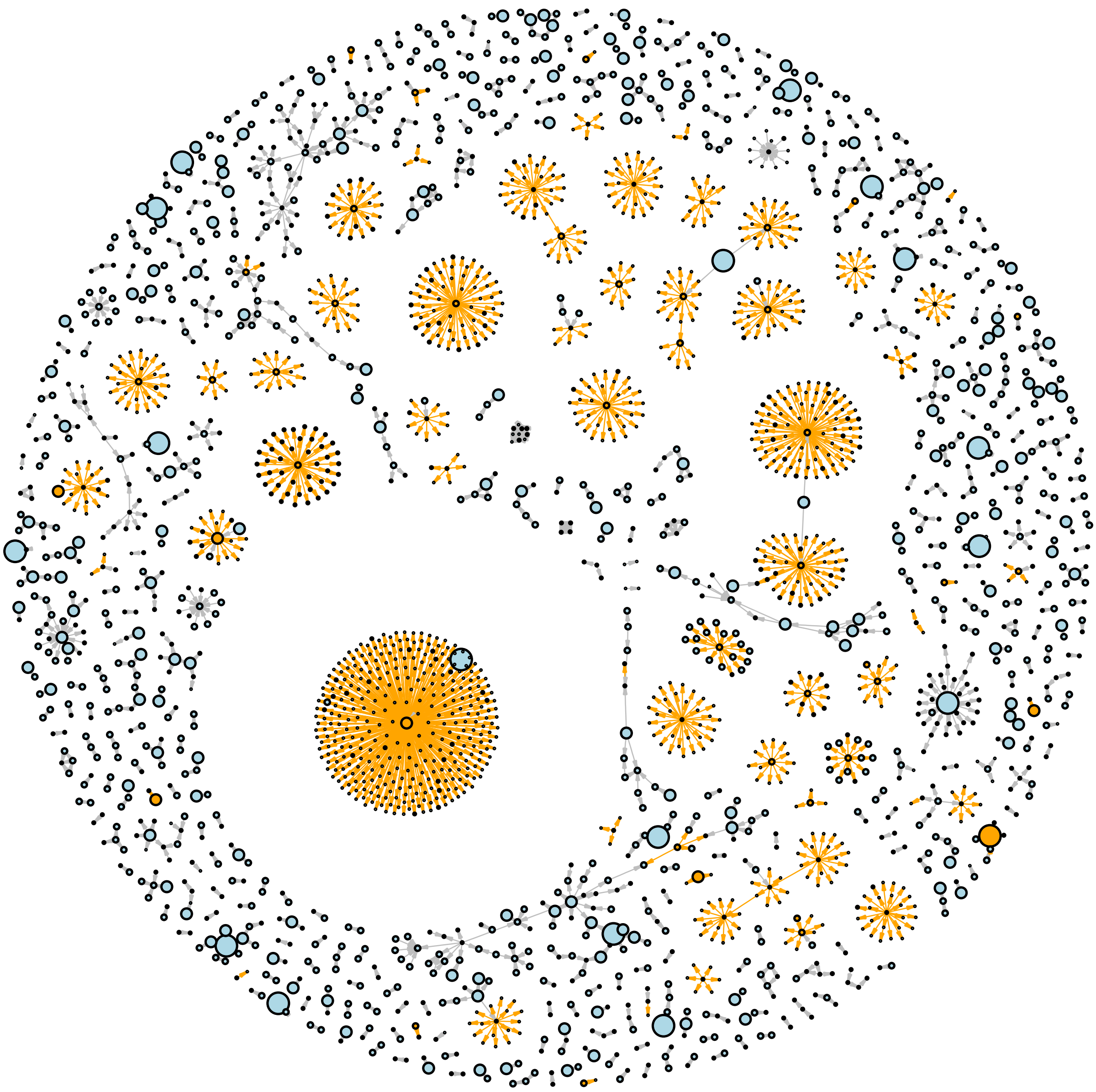

Figure 3. Family tree of Thingiverse's 'Toys & Games' category.

We analyzed the entire family tree by comparing and contrasting individual 'innovation families'. We found that each innovation family can be decomposed into distinctive remix patterns. In Figure 4 we list and briefly describe these patterns. Starting from three basic patterns (linear evolution, merge, fork), we characterize seven compound patterns which reappear across Thingiverse's family trees. These distinctive remix patterns can be grouped into two categories – reduction and expansion of the innovation space. Going forward, we hope to gain a deeper understanding of how existing ideas are recombined and where innovations come from.

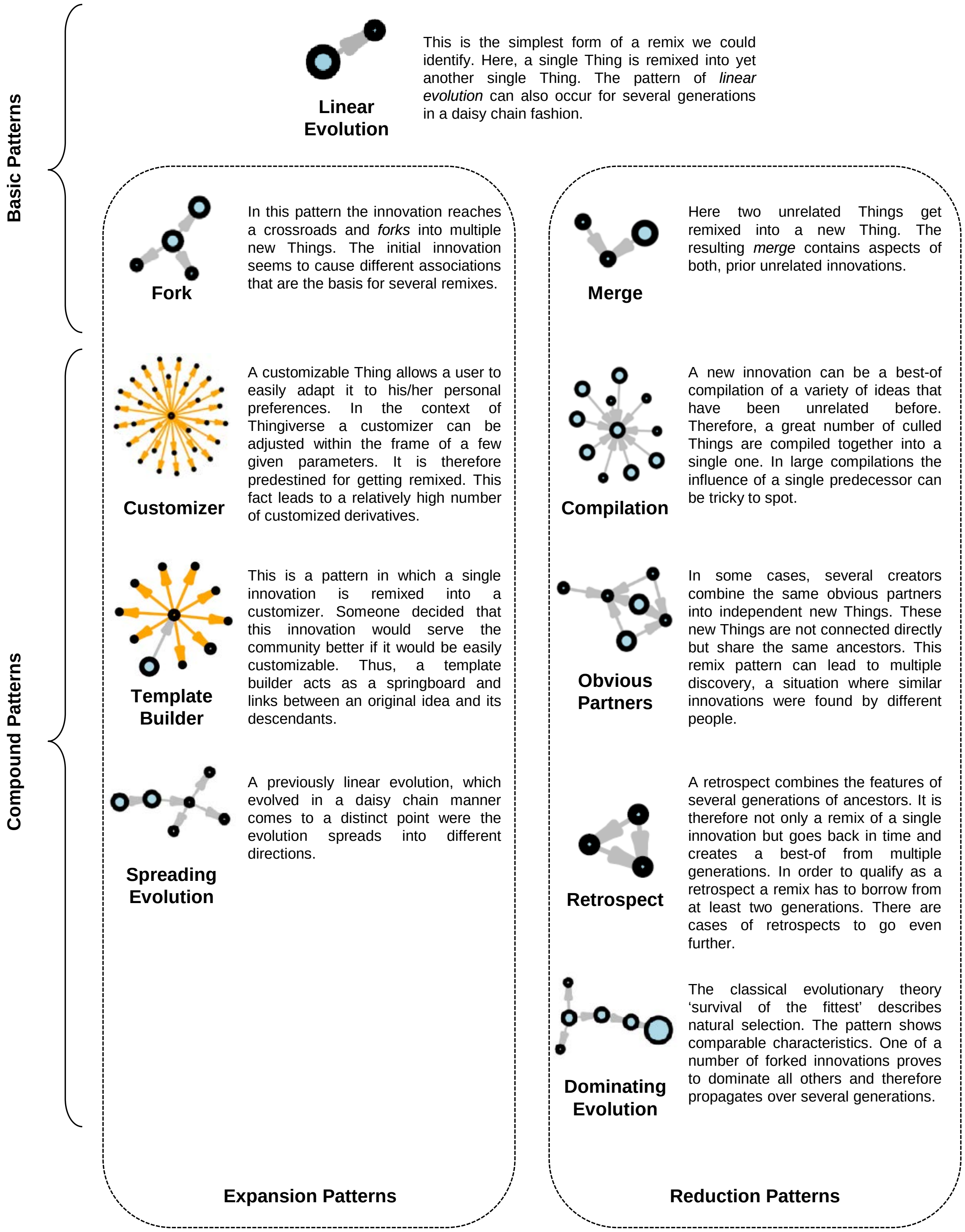

Figure 4. Overview and description of remix patterns.

5 Discussion

Most innovations are recombinations of already known elements (Schumpeter, 1942; Salter and Alexy, 2014). Yet, how these known elements can be brought together to form an innovation has only been answered to a limited degree. Research has focused either on the creative process (in the individual or a group) or on the processes that happen inside of corporations. We put the innovation itself in the center of our study to develop patterns that we hope can be applied to all kinds of innovation settings. Group creativity for instance is often a simultaneous process while other innovation processes can happen sequentially. We have examined Thingiverse—the leading online platform and community for 3D models—to shed light on the question of how the recombination of known elements can lead to innovations. We showed that this 'remixing' of already existing Things follows ten distinctive patterns.

The developed ten remix patterns do not only extend our theoretical knowledge on innovations, they can also help practitioners design innovation processes. Here, the distinctive patterns can be applied to structure creative processes. Solutions that might otherwise be overlooked can now systematically be screened for. Innovation teams can, for instance, search for new solutions by applying one pattern after the other, which should lead to different solutions for the same problem statement. It is also imaginable that different groups could be given different patterns as guiding principles to let them develop solution to a current problem.

Although currently there are more than 200,000 Things with more than 120,000 remix relations among them, our analysis only looked at a snapshot of the available data. Because of that, we plan to implement the following steps. First, we are going to expand our analysis on all of Thingiverse's categories to find similarities and differences among them as well as the leaps of ideas between them. Furthermore, we plan to collect quantitative evidence for the presented patterns to complement this explorative study. A third aspect of our future research will be the combination of remix patterns and quantitative metadata. Thereby we want to consider questions like whether specific remix patterns have an influence on the popularity of a Thing.

One major limitation remains at the present stage of our research. We assume that the Things available on Thingiverse are representative of innovations in general, as they are simultaneously digital models as well as physical things. We are aware of this generalization and will see to address it as our research in progress continues. Given the differences among the Things we investigated, we assume that these ten distinctive patterns have merit outside of Thingiverse, too. However, at this point in our study we are not able to show the generalizability of the developed remix patterns. To do so we would need to apply the patterns in different settings/industries. It would be desirable to do so for instance in the music industry, an industry which is also known for its heavy us of remixes (Lessig, 2014). It is also plausible to collect case studies from different industries and map them with the remix patterns we have found. Such a qualitative research approach would, in our view, complement the research presented here well.

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