1. Introduction:
Emerging digital design processes in architecture are vividly reshaping the field as they provide new theoretical approaches and generate new Forms. Thus, we now see architects and designers being liberated from past constraints of formal ideation and traditional modes of construction (making). Within this context of design freedom new design criterion are evolving to provide a reference framework for the pluralistic approaches provided by emerging digital design processes. This includes both conceptual form generation and the making of architecture. This paper provides a glimpse at the emerging use of technology as both an artistic irrational exploratory tool and a scientific rational focusing methodology. Ultimately, it is our claim that designer values dictates the means and method of technology infusion in architecture and the resultant Form is the result of both technological and human evolution.

2. Digital Tools in Exile
If not the ultimate pioneer, Frank Gehry is definitely one of the leading practitioners who paved the way to the utilization of technology in architecture. The curvaceous Disney Concert Hall and Bilbao Guggenheim Museum are manifestations of technology impact in architecture (Barrow, 2000). However, ironically, Gehry’s design philosophy regarding the computer is summarized in this quote, “The Computer is a tool, not a partner… an instrument for catching the curve, not inventing it.” Thus, for Frank Gehry digital tools are “exiled” from the initial conceptual stages where he relies instead on traditional hand sketches and manually built physical models to capture his aesthetic vision (Fig 1). Gehry's designs are generally inspired by nature, borrowing his curves from animal figures as in the case of the Olympic Fish, or by echoing the surrounding natural elements as in the Bilbao Guggenheim Museum.

![Fig 1. a) Gehry’s conceptual hand sketch for the Disney Concert hall. b) Physical model. C) Construction phase utilizing CNC capabilities for the building façade.](image-url)

The role of digital tools for these two famous projects relegated technology to the later phases of design development. Digitizers were utilized to scan manually produced models
and translate the “shape” geometrical information to obtain digital models. Once digital, this 3D data enabled further detailing for structural system coordination and metal skin production. Thus, following a traditional conceptual paper sketch and physical modeling schematic design phase, technology was used extensively for design development and CADCAM for construction. Hence, in these projects, we see the key role of digital tools was to bring otherwise “unconstructable” curvaceous forms to realization.

3. Digital Tools in Control
On the opposite end of the spectrum, there are architects who are enthused by technology’s capacity to generate unpredictable Form. Undoubtedly, one of the prime figures in this group is Greg Lynn who expressed: "If it comes down to it, I would have to give the software 51 percent of the credit for the design of my buildings." Lynn relies on software environments used typically in the film industry to support his design approach. Typically, Lynn uses the imposition of dynamic forces extracted from the project’s context; these include physical site constraints, building program, circulation schemes, external environmental influences, building type, etc. These dynamic force factors are imposed on a preliminary shape in reference to “time.” Lynn’s forms are often extracted from nature; such as the use of wind forces to generate the shape of the H2 House; other examples are the Embryo House where growth development of the embryo was used as the conceptual basis (Fig 2). Thus, technology plays a significant role in the conceptualization of the design. However, translation of these digital forms into actual architecture is limited as the majority of Lynn’s work remains un-built and is thus limited to theoretical and digital form exploration.

Similarly, but perhaps to a lesser extent, Bernard Franken utilizes digital environments used in the film industry too as a means of generating forms that communicate certain expressions. Hypothetical digital forces relating to the context of the expression pursued are applied to the digital form exploration; deformations and morphing operations evolve through experiments to generate new Form. Franken’s BMW pavilion evolved the “Bubble” around the concept of merging water drops (Fig 3). Further detailing and design development occurs through the use of specialized software that supported structural, energy and other detailed analysis. The construction of Franken’s designs likewise, heavily depends on the use of CNC capabilities to transfer data from the digital models to the construction site. Hence, this second approach greatly depends on digital tools from its conceptual outset to the final construction stages.

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Fig 2. Embryological house by Lynn.  
Fig 3. “Bubble” BMW Pavilion by Bernard Franken.
4. A Moderate Approach

A mid-ground between the two former approaches is that found in the work of Foster & Partners and SHoP architects; here we see a more eclectic philosophy. Parametric modeling environments are utilized to create models that are based on the definition of relationships between the parts and components of the building; this is done in lieu of absolute geometrical values of the building components. As the values governing these relationships are changed and set adhering to site and project constraints the form of the building gradually evolves. This process is initiated by a preliminary form concept for which the Smart Modeling Group (SMG) at Foster & Partners provides one or more digital models that represent the basic features of the form of this initial concept. Architects evolve this first idea based on rational “rules” specific to each project. As an integral part of Foster’s philosophy, great attention is given to sustainable design, energy conservation and climatically related issues (Fig. 4). Digital capabilities allow Foster & Partners to explore design factors on a wider scope in the conceptual design stage.

Following a similar philosophy, SHoP Architects embrace the business and financial aspect of the profession as a major player and decision making factor. Often, architects evade dealing with issues related to site restrictions, choice of materials, structural and systems realities and the client’s budget constraints until after the conceptual basis and the form is determined; SHoP deals simultaneously with these restrictions as it develops the early project concept. Thus, SHoP embraces these constraints as opportunities to allow such factors to mold the form of the project (Fig. 5). The computer’s role within this setting is to provide the environment through which project constraints are recorded and facilitate the interaction between such information and the architect’s ideas in order to generate the final form. Greg Pasquarelli of SHoP describes the process:

“As information is gathered from the contractors, the clients and our design idea, we can feed that into the model, then the form moves and adapts, but the design keeps its integrity….We really feel that our buildings improve as more restrictions are placed on them.”

Fig. 4: a) The City Hall in London By Foster evolved from the form of a pebble which was further shaped through b) sun studies and energy analysis.

Fig. 5: a) The Fashion Institute of Technology by SHoP b) Digital Façade study base on site considerations and budget.
5. The Industrial Design Approach
Manufactured products today are typically appealing in terms of their form and aesthetical qualities. This is achieved through the integration of mass-production and customization in the design and manufacturing approach adapted in Industrial Design. Here the traditional linear design-build approach typically followed is abandoned in favor of a more collaborative approach that brings together all those concerned in design and manufacturing at the outset of the project (Jarvinen & Koshinen, 2001). This allows the role of technology to be integrated holistically to ensure that an optimum design and manufacturing methodology is pursued. This allows for production, based on thorough research, which takes into account not only the capability of digital tools to support the design and manufacturing of fluid forms; additionally other performance aspects and consumer demands can be studied and accommodated in the design-make process. Business and marketing tactics are integrated as well. Within this collaborative framework, Form is not a pure manifestation of the designers creativity and digital capabilities as much as it is a by product of several factors, most prominent of which are performance requirements (Fig 6).

Often technology is thought to be Hardware (HW) and/or Software (SW). However, our research in related fields of manufacturing (i.e. automotive and aerospace industries) provides a broader definition of technology that is relevant to our discussion. As early as 1986, Zeleny defined technology to be inclusive of three interdependent, co-determinant, and equally important components; 1) Hardware – physical devices, 2) Software – algorithmic codification languages, and 3) Humanware – people and the “reasons” for using the HW+SW (i.e. the computer) (Noori 1997). This definition of technology is paramount; it points to the purpose of computing and places a high value on “human” engagement and humanistic qualities. Thus, technology includes people; in architecture this means the “designer” and WHY and HOW they choose to use and leverage digital tools and CADCAM processes.

6. Conclusion:
As observed, approaches to utilizing technology by architects as a form generating tool varies from total rejection to total submission (Table 1). It is also observed that architectural form is a result of not solely the digital tools adapted in the form generation process but also the combination of these digital capabilities and the human values that drive the design process. The two extremes overviewed in this paper do however share one common factor, nature the source of inspiration from which form is extracted. Yet this attempt to mimic natural forms, as illustrated by these extreme approaches, could be deemed superficial when compared to the actual complexity of natural beauty that combines function and
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performance not to mention a total ecological fit within its surroundings in a minimalist fashion that is sadly but inevitably absent in these strategies to technology incorporation.

Table 1

<table>
<thead>
<tr>
<th>Phase</th>
<th>1st Approach</th>
<th>2nd Approach</th>
<th>3rd Approach</th>
<th>ID Approach</th>
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<tbody>
<tr>
<td>Form Generation</td>
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<td>√</td>
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<tr>
<td>Design Development</td>
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<tr>
<td>Making/Construction</td>
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<td>√√</td>
<td>√√</td>
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<tr>
<td>Technology not used</td>
<td>√</td>
<td>Technology used minimally</td>
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<td>√</td>
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<td></td>
<td>√√√</td>
<td>Complete dependence of digital tools</td>
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The third philosophy towards the integration of technology in architecture could be compared to that followed in Industrial Design (ID) where a holistic strategy is followed to integrating technology in the entire process of design and realization. This strategy ensures that optimum tools are used regardless of their degree of novelty to define form based on numerous factors that include functionality, budgetary restrictions, consumer appeal, and environmental considerations, while highlighting performance aspects and manufacturing requirements. The forms generated through this process, though not as elaborate as those in the former two approaches, do not lack aesthetical appeal. They do however have additional qualities pertaining to performance and energy conservation aspects.

While the sophistication and beauty of forms arrived at through this third moderate approach is still far from that found in nature, we venture to question whether this means that architecture could gradually adapt an industrial design philosophy to govern the integration of the tools that had originally migrated from the ID field. We foresee the possibility for further integration of digital “thinking” into the architectural design/making process as seen in ID; this holistic systems design approach could arrive at forms that more closely echo natural beauty beyond the superficiality of shape and originality of aesthetic.

Technology is being used to emulate nature for conceptual inspiration as well as form aspirations that derive its essence from natural factors and sustainable systems. Thus, we see the evolving paradigm shift in form-finding to be inherently interwoven with Technology; that is both machine (hardware + software) and man (human values). Hence, as person-kind evolves with our interwoven relationship to machines and nature, Form Follows Technology.

7. References: