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DERIVING A COMPONENT BASIS FOR COMPUTATIONAL FUNCTIONAL SYNTHESIS

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Abstract

In this paper, we present our findings on the development of a design naming convention for electro-mechanical components. We have two main objectives. First, we aim to arrive at a standard set of names to derive uniformity and consistency in the representation of components and to improve communication of design information both in industry and in design education. Second, we strive to establish a framework for future computational tools that supports archival, search and reuse of component design knowledge.

Keywords: Function structures, functional modeling, ontology of electro-mechanical components, concept generation, design reuse.

1 Introduction

Computer-aided tools contribute greatly to the detailed design stage of product development thanks to formal design representations developed to support modeling, simulation and analysis. Early phases of design, however, have yet to fully benefit from advantages of computational tools. It is proposed that the difficulties hinge on a lack of thorough computational component representation. Ideally, a computational representation for mechanical components would combine dynamic behaviors, shape information and the functional intent of a component. Unlike electric and electronic components, mechanical systems have defied a formal representation thus impeding computational synthesis and analysis of a conceptual structure or configuration.

Clearly the task of defining and organizing all mechanical, hydraulic, electrical elements appears insurmountable. Given the number of components used in the past as well as the fact that new components are being created all the time, one would need to dedicate their life's efforts to defining such a catalog. Fortunately, advances in the internet and object-oriented programming offer some respite in achieving such a goal. If a defined yet malleable hierarchy is created (as in object-oriented programming), it is possible to build an online repository of all such components as a world-wide community effort. The repository would be leveraged by various computer applications to improve our abilities at computationally modeling and designing at the earliest stages of the design process.

This paper describes ongoing research into the creation of an online repository. The goal of the paper is not to capture all components, but to create subcategories or names for all components to fit within. Through both empirical dissection of existing products to defining categories based on simple physics principles, we define 92 component types. In the following sections, we will discuss other approaches to cataloging components, and the use of such a catalog for further computational synthesis (Section 2: Background). This is followed by a description of the method we use to arrive at the component names (Section 3: Methods), and our presentation of our findings (Section 4: Results). Next, we show preliminary results of using the repository data to create new designs (Section 5: Application), and conclude with a discussion of the results and future work (Section 6: Conclusions).

2 Background

Several researchers, institutions and corporations have developed systems to capture abstract engineering design models such as functionality or interface requirements. The captured models range from detailed function and behavior information to loose hierarchical artifact relationships. One of the early systems, described by [1], used a block diagram approach based on "function logic" and was powered by Hypercard stacks to navigate function diagrams. Their representation schema was built on function logic to describe complex systems and included mathematical relationship equations in relationship to the "function blocks." The more thorough NIST Design Repository Project is a framework capable of storing component information and how the elements of information are related to each other [2,3,4,5,6,7]. Within the NIST model there are five sections: Artifacts, Functions, Forms, Behaviors and Flows, which contain information relative to their denoted name. Similar function-based representations have been proposed by others to support search and modeling processes of conceptual design [8,9,10,11].

The functional structure concept developed by Pahl and Beitz [12] provides a general and powerful representation of a design during conceptual stages. Researchers at University of Missouri-Rolla, University of Texas at Austin, and NIST have developed a standard vocabulary for describing the basic functional blocks for electro-mechanical design problems. This effort has culminated into a functional basis language that includes a set of terms that span the space of all functions and all flows [13]. Here, a function refers to a transformation operation from input flow to output flow. Functions are used in verb-object format. For example a motor "converts electrical energy to mechanical energy." Three sets of function terms are defined to allow three levels of abstraction for allocating functions to a system. Tables 1 and 2 show a portion of the functional basis. Using this functional vocabulary, device function can be defined for a given system using a functional model. Ongoing research includes methods to build parametric performance models, identify potential failure modes, redesign to avoid failure, automatically generate potential physical solutions and develop product family platforms all based on functionally represented and stored design knowledge.

From a perspective different than the functional modeling approach, a number of research efforts have sought to establish an automated scheme for generating electromechanical designs. While these methods have yet to capture *function* on the same level discussed above and as it is understood by human designers, such approaches have been used in attempts to synthesize new electromechanical configurations. These methods use a variety of computer techniques including case-based reasoning [14], constraint programming [15], qualitative symbolic algebra [16] or geometric algebras [17]. One of the most historically significant of these includes several approaches applying expert system formulations to specific design

Table 1. Function examples from the functional basis [13].

Class	Basic	Class	Basic	Class	Basic
Branch	Separate	Control Magnitude	Actuate	Signal	Sense
	Distribute		Regulate		Indicate
Channel	Import		Change		Process
	Export		Stop	Support	Stabilize
	Transfer	Convert	Convert		Secure
	Guide	Provision	Store		Position
Connect	Couple		Supply		
	Mix				

Table 2. Flow examples from the functional basis [13].

Class	Basic	Class	Basic	
Material	Human	Energy	Human	Mechanical
	Gas		Acoustic	Pneumatic
	Liquid		Biological	Radioactive/Nuclear
	Solid		Chemical	Thermal
	Plasma		Electrical	
	Mixture		Eletctromagnetic	
Signal	Status		Hydraulic	
	Control		Magnetic	

problems such as the paper roller system established by [18]. In the approaches reviewed, the repeating refrain is that computational synthesis approaches produce an overwhelming number of concept variants – even for limited domains – and a pruning method is needed to realistically identify all feasible solutions [19,20].

The A-Design representation [21], which is both formal and implemented, captures the interactions between individual components even if such interactions represent only partial configurations. Similar to approaches shown above, the representation is based on the notion that a component can be viewed as a black-box or a control volume with inputs and outputs that feed into other boxes. This research extended the representation developed by Welch and Dixon [22] which further extended the work of Ulrich [23]. The work of Ulrich combined bond graphs (models of dynamic behavior; Paynter, [24]) with the design methodology posed by Pahl and Beitz. The representation developed here aims to relate components in terms of their dynamic behavior, shape, and purpose. In this way, the research is similar to other dynamic simulation methodologies such as those presented in [25] and [26]. One should note that in general libraries of components are developed for a specific application. Within the variety of computer-aided design research, various methodologies and tools have been developed which require a rich set library of components. Therefore, the goal of this project is to arrive at an initial creation of a library that can be used by a number of design automation methods.

3 Methods

Returning to the NIST-University collaborative efforst, recent progress has established the concept of an Enhanced Bill of Materials (EBOM) that handles entry, management and export of repository knowledge. All design knowledge corresponds to a single artifact (which may itself be composed of additional subartifacts), suggesting that an efficient EBOM should similarly be focused and indexed around each single artifact. Currently, the EBOM concept is implemented in a database using FileMaker Pro. A partial screenshot of the interface of FileMaker is show in Figure 1.

Following entry and storage into FileMaker, a platform-independent data set is output as XML. By creating JSP (JavaServer Pages) the XML from the database server can be viewed as HTML through a standard web browser [27,28,29] as shown in Figure 1 (b). Currently the repository (http://function.basiceng.umr.edu/repository/) focuses on storing and organizing design artifact information as opposed to using that information to develop further design methods. For purposes of addressing the full scope of design data, we expect that the inclusion of additional information is feasible. As a summary of the current web-based system, three main interaction modes of use are supported: browse, search, and process design tool output. In the browse mode as shown in Figure 1b, artifacts in the repository can be selected on the left pane and inspected on the right. The search mode allows the user to search for all artifacts that match an input selection. The final mode of operation includes the execution of certain design tools including the function-component matrix, design structure

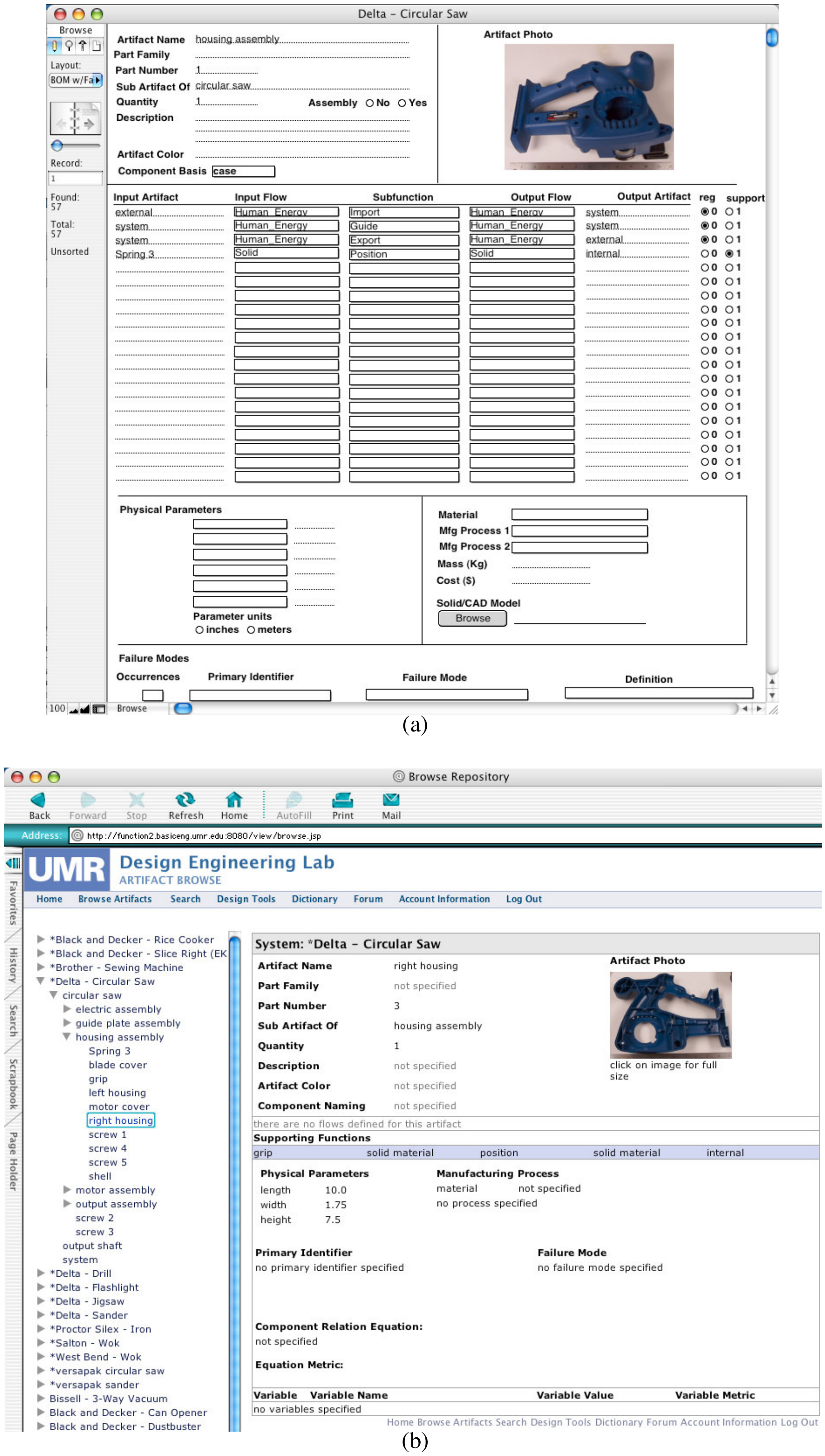


Figure 1. (a) FileMaker input screen and (b) UMR design repository web interface.

matrix, bill of materials, and soon to be implemented functional model and parametric model outputs.

Based on the success of defining a canonical list of function and flow names as shown in Tables 1 and 2, a similar project sought to define a canonical list of component names [30]. Our study builds upon this research which surveyed various technical references (design texts, catalogs, etc.) to categorize component names of mechanical, electrical, and hydraulic elements. This research defined 114 terms under four major classes: functional forms, geometric shapes, simple machines and nature. The classification scheme, however, is mainly observational. Two of the classes (nature and geometric shape) are organized according to component form then component function. This is inconsistent with our view that *function* is the fundamental ontology of a component especially at the conceptual phase of design, where efficient indexing, search and retrieval of information is facilitated by function-based queries. With this perspective, we have redefined a basis set of component names.

Our research includes two primary steps: an empirical study and a derivation of component names and their definitions. In the empirical study, we dissect a variety of consumer products and record the relationships between components and functions. This information is stored in a matrix as described in [31]. In conducting the study, we strived for two goals: *completeness* and *exclusivity*. The completeness criterion is defined as the measure of how well a list of components enumerates all the elements of all electro-mechanical devices. Exclusivity is defined as created component types that have the least overlap or redundancy to other component types. In general, completeness is accomplished automatically with an empirical study of existing product. As shown in Figure 2, it is likely that with each additional artifact that is dissected and catalogued in the repository, the return in the number of new components begins to reduce. Of course, a large number of artifacts would need to be dissected before a change in the rate of new types is noticeably decreased. A similar graph was constructed in the function structure research to arrive at a finite set of function names as can be seen in [32]. The challenge in such research is to avoid violating the *exclusivity* criterion. Every new component may indeed challenge the accepted component types defined so far. For example, imagine that the first dissected artifact is held together purely by screws (see Figure 3a), and screws are defined as an official component name. Then, the second product is dissected and one finds that it is comprised of bolts and nuts (Figure 3b) – fasteners unlike those found in the first product. One must concede that they are the same component type since they perform the same function although they commonly are referred to differently. In building on the research presented in [30], we found that of the 114 components defined, some were, in fact, subsets of others. Our efforts at defining an exclusive set of component names lead to a reduced total of 92 components.

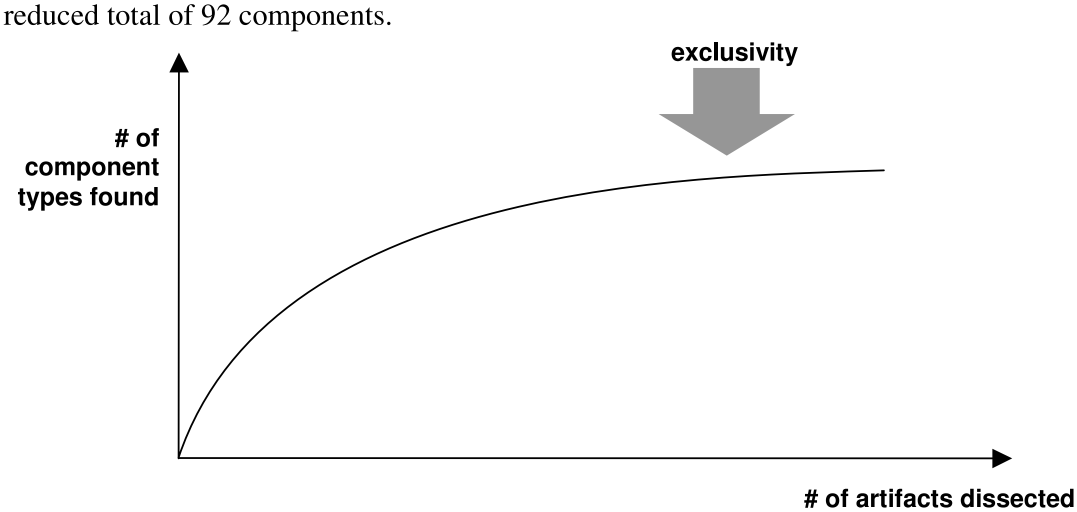
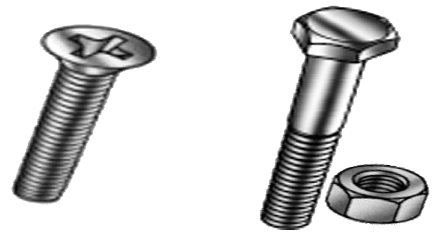


Figure 2. Through constant empirical testing one can achieve completeness; however, one must be careful to heed the exclusivity criterion.



(a) (b)

Figure 3. Two simple fasteners (a) a screw, and (b) a nut and bolt point out the difficulty in defining component names that satisfy the exclusivity criterion *(Figures courtesy of McMaster.com).*

As opposed to taking an empirical approach, which is time consuming and prone to violating the exclusivity criteria, one may adopt a more idealistic approach to defining components. Many of the related research projects discussed above define a simple set of components upon which to develop their methodology. For example, the A-Design research [21] is based on a set of 32 component names of which there were approximately 10 instantiations of each component. In Welch and Dixon, 52 components were defined by the author without the rigorous dissection of actual artifacts. It appears that this approach of defining names purely based on physical principles suffers from the opposite problem that the empirical study suffers from. It is much easier to be exclusive in component names but difficult to be complete.

In the last year of defining component names, we have adopted both approaches. That is, we both create component names based purely on what we know about the wealth of engineering artifacts and their components' functions, and we dissect actual artifacts to find component names through brute-force observation. Figure 4, shows a plot of the number of components as a function of time. Note that striving for completeness makes the number of components types increase, while vigilantly policing the names for redundancy or exclusivity may drive the number down.

In general the authors believe that there are in fact hundreds of component names. However many of these beyond the initial 92 presented here will happen quite rarely. Our convergence to a value that is in the neighborhood of 100 is simply a result of not having dissected more artifacts. Still within this set there are countless issues of exclusivity. There are components such as the threaded-fasteners shown in Figure 3 which exist in nearly every artifact and thus one must be careful to define proper component names to describe these.

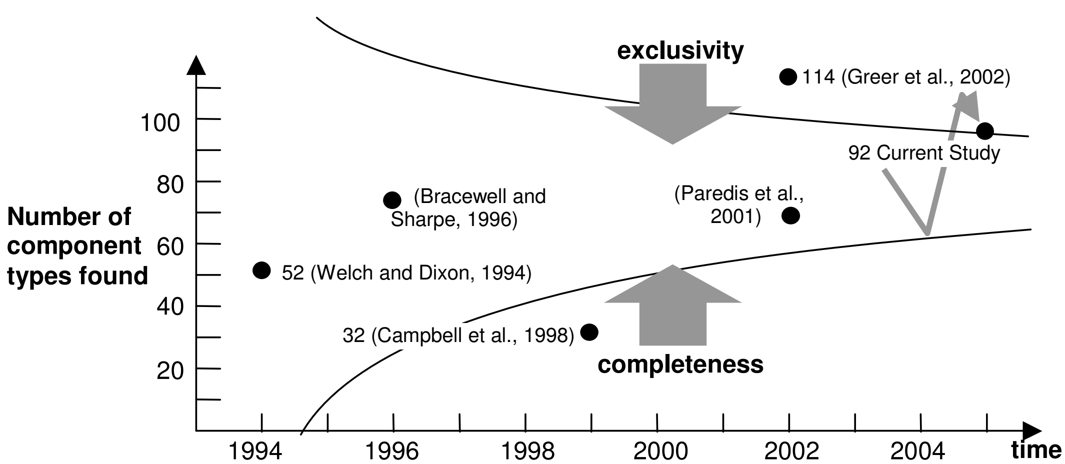


Figure 4. A plot of past efforts to define a set of complete and exclusive component names.

4 Results

Fourty-one consumer products have been used in the derivation of the abstract component names. The resulting basis set defines 92 unique components. The list is organized such that each fundamental component name is presented with its synonyms and a definition. The basis set is shown in Appendix.

To validate the basis, we build two aggregated function-component matrices as is shown schematically in Figure 5. The first function-component matrix (or FCM) maps how each of the 1002 individual components of the 41 products map into the 188 functions defined by creating function structures for each artifact that is dissected. This FCM is then compared to a reduced FCM created by mapping the 92 component names to the 188 identified functions. The result showed that all 188 functions were captured by only 78 of the component names. The remaining 14 component names had been defined by “first principles” that is through intuition or by adopting elements from the 114 specified by Greer et al.

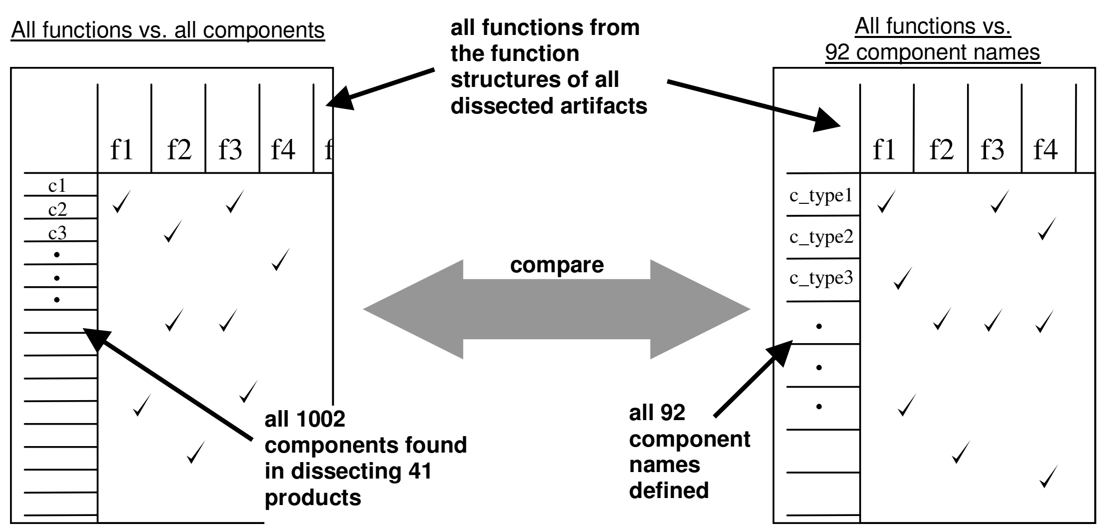


Figure 5. Schematic of the two aggregated function component matrices build for validation of the basis.

5 Application

In this section we discuss two applications that are in development which require a thorough online repository. As is discussed in the Introduction, the repository affords the use of computer tools earlier in the design process. A standard set of component classes would allow the development of a wealth of design automation tools. In the two examples shown below, researchers are banking on the functional representation included in the repository to allow for a computer to determine what components are needed to instantiate a given functional description of the design problems.

5.1 Grammar Based Concept Generation

Based on the FCM data, researchers examine the relationships to identify popular trends in the various ways that functions are fulfilled by components. These trends are then defined as grammar rules. In recent years, engineering researchers have discovered that shape grammars, which were originally used in architectural research [33], provide a flexible yet ideally structured approach to engineering design methods [34]. A shape grammar is a set of shape rules that apply in a step by step way to generate a set, or language, of designs. Grammar

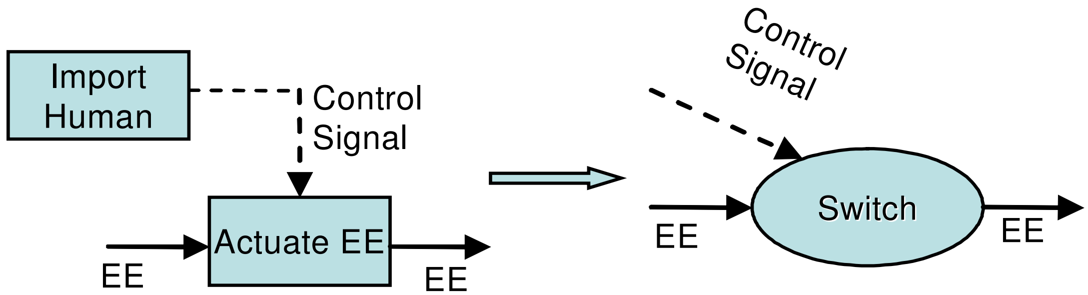
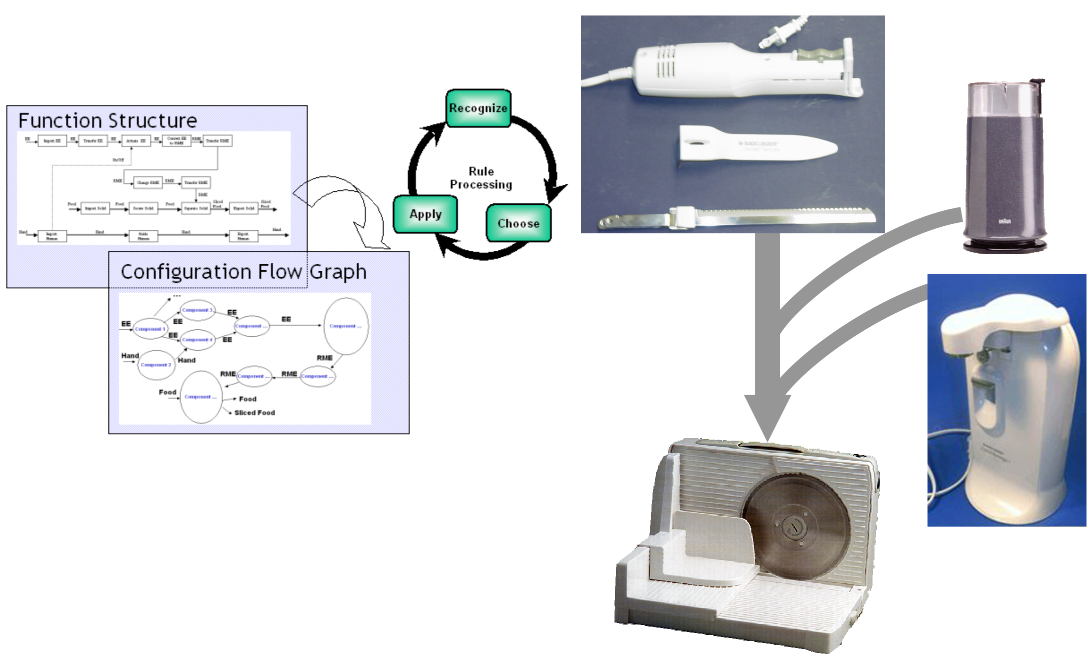


Figure 6: An example grammar rule that recognizes the functions "import human" and "activate EE" in the function structure and inserts a switch into the configuration flow graph (CFG).

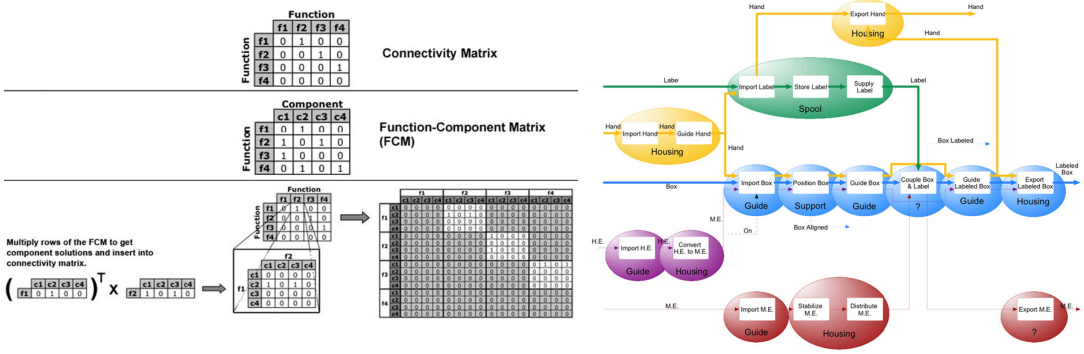
based design systems offer the option of exploring the design alternatives as well as automating the design generation process. The concept of a grammar is that an experienced designer can construct a set of rules to capture his/her knowledge about a certain type of artifact. The grammar can be constructed such that any execution of the rules creates a feasible solution [35] or captures the style of a specific period [36] or a specific designer [37]. Thus far, 45 rules have been developed; an example rule is shown in Figure 6. The rule includes a left-hand-side that must exist in the function structure for the rule to be applied. The resulting transformation is then depicted in the right-hand side of the rule.

The basic generation process for a set of rules is to first recognize which rules have left-hand-sides that match the current state, then choose one of these rules, and finally to apply the rule as a step towards constructing an alternative [38]. In this research, the function structure acts as an input to the process, which return a configuration flow graph (or CFG) as an output (see Figure 7a). In [39], we discuss how rules derived from three household products can be used to create the CFG for a new artifact (see Figure 7b).



(a) (b)

Figure 7. a) Building the configuration flow graph from a function structure using the rule set. b) In [38], the rules derived from an electric knife, a coffee grinder, and a can opener are used to derive the configuration for deli slicer.



(a) (b)

Figure 8. a) In a second approach to concept generation, the FCM is used as the first of many matrices that are multiplied together to create a set of possible component sets that instantiate an initial function structure. b) An example in Bryant et al. shows how information from the FCM is used to create a CFG for shipping box labeling device.

5.2 Matrix-Based Concept Generation

In this second approach, researchers again use the FCM extracted from the repository as their starting point in determining how components may be chosen to meet the functional specifications of a design problem. In this approach, the FCM is pre-multiplied by a series of filter matrices comprised of 1's and 0's. The filter matrices reduce the FCM to a reasonable set of combinations of components that meet the design needs as shown in Figure 8. A recent paper [40] details how this approach can be used to create a connection of components (as is similarly done in the CFG in the previous research) to solve the problem of a box-labeling device to assist workers at a local area workshop for persons with disabilities.

6 Conclusions

The goal of this research has been to take on the difficult and tedious task of defining standardized names for all possible mechanical, electrical, and hydraulic components. To our knowledge, the task has not been attempted before outside of the study performed by Greer et al. We believe that such an undertaking could be accomplished through a worldwide collaborative effort that is afforded by the internet. We further describe important criteria for such a repository: *is it complete*? and *are the names exclusive*? Perhaps the challenge of exclusivity is much more difficult than that of completeness. In fact, leveraging the internet would likely result in a set of component names that are highly redundant (the opposite of exclusivity). Therefore, we have set out to define initially a set of component names into which other researchers may add specific components. Initial validation has shown that the 92 component basis terms cover a wide range of functions. The resulting basis could be expanded to include more components by examining more products. It is likely that the basis will slowly converge to a finite value through the dissection of new products. For the perspective of our research, we are now using this basis as a set of fundamental elements for functional synthesis tools to automatically construct new designs from functional specifications.

The results of arriving at such a thorough repository are not simply useful to computational design synthesis research. Arriving at a standard set of names to represent electro-mechanical components could be useful to vendors selling a variety of original equipment manufacturer's components (OEM components). Furthermore, a wealth of dynamic simulation tools such as Dymola [41], Working Model [42], and Schemebuilder [26] could use the repository component names to allow for easy user familiarization and interoperability. Also, the interactions between engineers could be ameliorated by an established set of standard names. It is the authors' hope that such as standard set of terms can be defined. Our set of 92 may suffer from some inconsistencies or language biases but perhaps the method provided will initiate a rigorous approach to creating an online repository accessible to all design engineers struggling to find the proper components for their artifacts.

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Appendix – 92 Components Basis Names

Name	Synonyms	Definition
Acoustic Insulator	Silencer	The material that provides the condition of being isolated by non-conductors to prevent the passage of sound, or vibration.
Agitator	stirrer, mover	A mechanical device used to maintain fluidity and plasticity, and to prevent segregation of liquids and solids in liquids, such as concrete and mortar.
Airfoil	Wing	Each of the limbs or structures by which an animal or manmade craft is able to generate a lifting force.
Axle	stub axle, beam axle, axle shaft	A supporting member designed to carry a wheel that may be attached to it, driven by it, or freely mounted on it.
Battery		A device that produces electricity.
Bearing	journal bearing, thrust bearing	Any part of a machine or device that supports or carries another part that is in motion in or upon it, such as a journal bearing or thrust bearing.
Belt	strap,girdle,band,restraint,strip	A flexible band made of leather, plastic, fabric, or the like that is used to convey materials or to transmit rotary motion between shafts by running over pulleys with special grooves.
Bladder	baloon, inner tube, membrane	A device resembling any of various sacks found in most animals and made of elastic membrane.
Blade	cutting edge,knife,razor,scraper	The broad flat or concave part of a machine that contacts the material to be moved or cut.
Bracket	cantilever, console, corbel, strut	A piece or combination of pieces, usually triangular in general shape, projecting from, or fastened to, a wall, or other surface, to support heavy bodies or to strengthen angles.
Burner		The component of a fuel-burning device, such as a furnace, boiler, or jet engine in which the fuel and air are mixed and combustion occurs.
Cable	wire,lead,chain,rope	Metal wrought into the form of a slender rod or thread by the operation of wire-drawing.
Cam	eccentric,cam plate,camshaft	An eccentric curved wheel used to transform rotary motion from a shaft into reciprocating translational motion.
Cap	stopper,plug,bung	A piece of solid or firm material driven into or used to stop up a hole or aperture in which it tightly fits.
Carousel		A circular conveyor on which objects are kept in continuous motion.
Chip	integrated circuit, transistor	A small wafer of semiconductor material that forms the base for an integrated circuit.
Choke	throttle	A restriction in a pipe that reduces fluid flow.
Circuit Board	circuit card, board, card	A printed circuit that can be inserted into expansion slots in a machine.
Coating	inside layer, lining, facing, liner	Any material occurring or placed next beneath the outside one. A covering or coating for an inside surface. Material that lines or that is used to line especially the inner surface of a vessel or passage.
Comb	rake	A combing tool with curved or straight tines, used for gathering dispersed material.
Condenser		Any device or system that condenses a liquid from a gas.
Container	receptacle, receiver, holder	A component which receives and holds an artifact. A component into which another component or device may be put.
Cover	top, lid, hood, shield, shroud, guard	Anything that overspreads an object, with the effect of hiding, defending, sheltering, capping or enclosing it.
Cushion	filling, wadding, pad	Something soft, of the nature of a cushion, serving to protect from or diminish jarring, friction, or pressure, or to fill up hollows and to fill out or expand the outlines of the body.
Diode		A semiconductor device which conducts electric current run in one direction only.
Displacement Gauge		An external plate or face on which rotational displacement is indicated.
Divider	diaphragm, partition, panel, wall, barrier	A device that divides an area into smaller separate spaces.
Door	gate, flap, access panel, entrance	A movable barrier, usually turning on hinges or sliding in a groove, and serving to close or open a passage into a space.
Driveshaft	output shaft, input shaft, jack shaft, half shaft	A commonly cylindrical bar used to support rotating pieces or to transmit power or motion by rotation.
Electric Cord		An insulated conductor for household use.
Electric Insulator	insulation	The material that provides the condition of being isolated by non-conductors to prevent the passage of electricity.
Electric Motor	actuator, dc motor	A device that converts electricity to mechanical work.

Electric Resistor		An electrical device that resists the flow of electrical current.
Electric Wire	coil, transformer	A metal conductor that carries electricity.
Evaporator		Any device in which evaporation occurs, especially one designed to concentrate a solution.
Extension		A device allowing the movement by which the two elements of any jointed apparatus are drawn away from each other.
Fan	windmill, impeller, propeller	A device composed of blades around a revolving hub.
Flywheel	inertia wheel, momentum wheel	A circular device which spins on a central axis that can store angular momentum.
Friction Enhancer		Facing material attached to a device that is used to reduce heat and increase friction.
Gear	cog wheel,rack,pinion,ring,sun planet	Components working one upon another, by means of teeth, or otherwise, in order to transmit force and motion between rotating shafts or translating devices.
Gripper	grip manipulator,graber	Something that grips or grasps.
Guide	v-guide, channel, pilot, track, path, way, locating hole, pathway, trace, jig pin	Any device by which another object is led in its proper course.
Handle	handle,hand hold	A component that allows any action that is thought of as comparable to grasping something or keeping it in place.
Heat Exchanger	intercooler,platen,radiator	A device used for the transference of heat from one medium to another.
Heating Element	loop,spiral,helix	An electrical conductor used for heat generation via passing electric current.
Hinge	pivot,axis,pin,hold down, jam,post,peg,dowel	The movable joint or mechanism that provides for rotation about an axis, such as the revolution of a lid, valve, gate or door, etc., or of two movable parts upon each other.
Housing	main body, container, box, shell, holder, casing, crate, crust, chest, skin, armor, housing, skin, sheath, envelope, wrapping, cage, enclosure	A device fitted to contain or enclose other devices or items.
Hydraulic Coupler		A fitting, usually having internal threads only, used to connect two pieces of pipe or hose.
Inclined Plane		A surface sloped at an angle to the horizontal (or some other reference surface), which provides a mechanical advantage for raising loads.
Indicator Light		A light transmitter used often to indicate a signal status as in an on/off light.
Inductor	coil, transformer	A conductor or device in which an E.M.F. or current is induced.
Insert	grommet, eyelet, bushing	An object of one material around which another material sets, solidifies, is formed, or which is forced into it after it has set. A removable, soft-material lining (often metal) used to limit the size of an opening.A firm material used to strengthen or protect an opening or to insulate or protect something passed through it.
Junction	split, junction, yoke, fork	A component with two or more pronged extensions.
Key	half-moon key, cotter key, shear key	A piece of material which is inserted between other pieces; usually, a pin-, bolt- or wedge-like artifact fitting into a hole or space so as to lock the various parts together.
Latch Release	catch, pawl, lock	A device that is designed to hold or free a mechanism as required.
Lens		A piece of glass, or other translucent substance, with two curved surfaces, or one plane and one curved surface, serving to cause regular convergence or divergence of the rays of light passing through it.
Level Gauge		An external plate or face on which the amount of a fluid or solid material is indicated.
Lever	bar, peddle, rocker arm, lever arm	A rigid structure of any shape (a straight bar being the normal form), fixed at one point called the fulcrum, and acted on at two other points by two forces, each tending to cause it to rotate in opposite directions round the fulcrum.
Link	connection, pawl, rod, strut, brace, cross piece, girder	Any connecting part transmitting motive power from one part of a machine to another. A member designed to resist pressure or thrust in a framework.
Magnet	lodestone, electromagnet	A piece of lodestone, or a piece of iron or steel to which the characteristic properties of lodestone have been imparted, either permanently or temporarily, by contact with another magnet, by induction, or by means of an electric current.
Material Filter	clarifier, separator	An apparatus used to prevent the passage of undesirable constituents in a material flow.
Needle	spine, stylus	A slender, usually pointed, indicator on a dial or other measuring instrument.Any of various slender hollow devices used to introduce matter (as air) into or remove it from an object.
Nozzle	jet, injector, fuel injector	A device that exports a continuous stream of concentrated and well-defined incompressible or compressible fluid. A device for converting fluid pressure into fluid velocity usually with minimum loss.
Nut-Bolt	wing nut, lug nut, female screw	A perforated block having an internal screw thread, used on a bolt or screw for tightening or holding something.
Piston	ram, plunger	The working part of a pump, hydraulic cylinder, or engine that moves back and forth in the cylinder to control the passage of fluid.

Potentiometer	pot	An instrument for measuring direct current electromotive forces. An instrument used to adjust voltages in an electric circuit.
Pressure Gauge		An external plate or face on which pressure is indicated.
Pulley	step pulley	A wheel or drum fixed on a shaft and turned by a belt or the like for the application or transmission of power.
Pump		A mechanical device that moves fluid or gas by pressure or suction.
Punch	die, stamp	A device used to exert pressure on a material, as to compress, shape, or mark it.
Reservoir	cup, container, receiver, vessel, holder	Tank used for collecting and storing a liquid.
Rivet	Pop-Rivet	Heavy pin having a head at one end and the other end being hammered flat after being passed through holes in the pieces that are fastened together.
Rotational Coupler	union, compression coupling, clamping coupling	A device used to connect coaxial shafts for power transmission from one to the other.
Rotor	Disk, impeller, hub, spindle, nave, indexer, index head	Any circular object that undergoes rotational movement such as in an electrical machine, turbine, compressor, blower, wheel, or contactor.
Scoop	ladle, dipper, skimmer, shovel, bucket, scoop, spoon, cup	A concave utensil for bailing out, ladling liquids or removing soft material.
Screw	Jackscrew, power screw, drive screw, lead screw, set screw, machine screw	The general name for that kind of mechanical appliance of which the operative portion is a helical groove or ridge (or two or more parallel helical grooves or ridges) cut on the exterior surface of a cylinder. A long slender fastener consisting of a head, shank and external threads.
Seal	gasket, o-ring	Any means of preventing the passage of gas or liquid into or out of something, especially at a place where two surfaces meet.
Signal Filter		An electrical device that alters the frequency spectrum of signals passing through it.
Sled	shoe, runner, skid	A component either under or within a machine used to facilitate sliding of components relative to one another.
Socket	port, outlet, tray, dish, repository	A hollow part or piece, usually of a cylindrical form, constructed to receive some part or item fitting into it. (Female of cap)
Speed Gauge		An external plate or face on which revolutions is indicated.
Spring	cantilever spring, coil spring, leaf spring, plate spring, torsion spring	An elastic contrivance or mechanical device, usually consisting of a strip or plate suitably shaped or adjusted, which, when compressed, bent, coiled, or otherwise forced out of its normal shape, possesses the property of returning to it.
Sprocket		A toothed wheel that engages a power chain.
Stator	stator plate	The stationary part of a machine around which a rotor turns.
Stop	snubber, travel limiter,bumper	A device that is automatically activated by a predetermined displacement to limit the operation of a system.
Support	stand, foot, foundation, buttress, crutch, leg, seat, slab, scaffold, brace, bed, stanchion, reinforcement, base, pillar, column, joist, sole plate, anchor, pedestal, jig, fixture,table, underpinning, piling, bench, crutch, platen, saddle, prop, spine, backbone, undercarriage, caliper	Anything that holds up, or sustains the weight of a body. (includes beam, excludes bracket)
Switch	knob, button, flip-flop, toggle	Control consisting of a mechanical or electrical or electronic device for making or breaking or changing the connections in a circuit.
Thermal Insulator		The material that provides the condition of being isolated by non-conductors to prevent the passage of heat.
Thermostat		A regulator for automatically regulating temperature by starting or stopping the supply of heat.
Tube	pipe, cylinder, conduit, channel, duct, nipple, sleeve	A hollow body, usually cylindrical, and long in proportion to its diameter, used to convey or contain a liquid or fluid, or for other purposes.
Valve	louver, regulator, tap, flap valve, rotary valve	Any of numerous mechanical devices by which the flow of liquid, gas, or loose material in bulk may be started, stopped, or regulated by a movable part that opens, shuts, or partially obstructs one or more ports or passageways.
Wheel	rim, disk, tire	Any of various machines, devices, or the like characterized by a revolving circular frame or disk usually used to utilize translational motion.