"New Directions in Jewelry": a Close Look at Emerging Trends & Developments in Jewelry-like Wearable Devices

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ABSTRACT
As *wearables* are entering the domain of fashion, it is not uncommon to see criticisms of their unfashionable aesthetics and gadgetry that do not necessarily consider consumer preferences and a need to create desire for *wearable* objects. As other categories of *wearable devices*, *jewelry-like devices* are in the process of undergoing a profound and rapid change. In this paper, we examine 187 *jewelry-like devices* that are either already available on the market, or are at various stages of development and research. We then examine various parameters using descriptive statistics, and give an overview of some major emerging trends and developments in *jewelry-like devices*. We then highlight and propose directions for technical features, use of material and interacting modalities and so on that could be applied in the development of the future *computational jewelry devices*.

Author Keywords
Wearable devices; jewelry; computational jewelry; collaboration; multidisciplinary; design

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

DEFINITIONS
To minimize misunderstandings among multidisciplinary researchers that might be interested in findings of this paper, this section describes key terms and definitions, used throughout our research.

Jewelry
Jewelry (or British *jewellery*) is a term that commonly refers to forms of personal adornment, worn on the body. There are some basic categories of *jewelry*, such as brooches, rings, necklaces, bracelets, earrings, body-piercings, cufflinks etc. that take an incalculable variety of forms, driven by available technology and materials, as well as fashion along with personal and cultural preferences. With some occasional exceptions where categories overlap, *watches* are not considered to be *jewelry*.

Wearable devices
Wearable device (or *wearables*) is a general term that currently refers to devices, warned on or around body, including, but not limited to garments, shoes, accessories and jewelry that have input, output or both. This term excludes implants, prosthesis and hand-held mobile devices

Gadgets
Gadget is as an overly multifunctional device with short lifespan, excessive complexity and limited aesthetic [15].

Fashionable wearables
"*Fashionable wearables* are 'designed' garments, accessories, or jewelry that combine aesthetics and style with functional technology." [11]. The term includes computational jewelry, smart garments, shoes, watches, etc.

Jewelry-like devices
Jewelry-like devices is a general term, used here to describe a subset of *wearable devices* that occupy traditional places on the body as *jewelry*, but do not necessarily look like *jewelry* (for example *Nike Fuel band*[1a], *Mota*[1b] ring and so on). Although there might be some exceptions in the future, *wearable devices* such as *smart watches* and *fitness watches* are not considered *jewelry-like*, as they belong to the market sector traditionally occupied by *watches*.

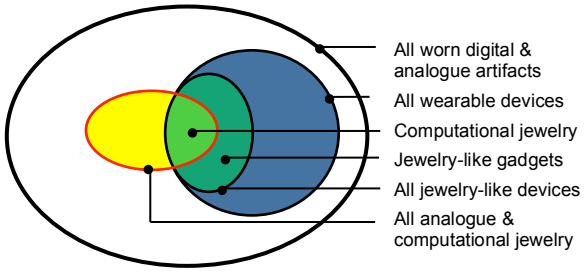

Figure 1 Computational jewelry diagram

[1] a) www.store.nike.com/gb/en_gb/pd/fuelband-se/pid-886061/pgid-886058; b) www.mota.com/doi-smart-ring

Computational jewelry

Computational jewelry (colloquially referred to as *smart* or *connected jewelry*, or in earlier research *digital* or *techno jewelry*) is a subset of *fashionable jewelry-like devices* (*Figure 1*). The term refers to the adornment artifacts that function both as *jewelry* and as a computational device [7].

INTRODUCTION

Since the 90es when the wearable computers meant just that: the computers with keyboard and screen [11][12], the realm *wearables* came to represent a vast variety of products. Among smart shoes, glasses, garments and many other categories, *computational jewelry* (as a part of a broader category of *jewelry-like devices*) is beginning to occupy distinct niche with specific trends, challenges and requirements.

It is possible that there are many unknown early examples of *jewelry-like devices*, but the earliest published example were two sentimental rings, made in 1994 by Nicole Gratiot Stöber [15]. Containing a small light that turns on when two lovers touched their hands, the rings were not particularly advanced devices. But they haled a tantalizing promise of new form of expression in jewelry that extended our sensibility and enchanted our existing adornments.

For a few years after the field of *computational* (or as it was then known, *techno* and *digital*) *jewelry* lay dormant, until researchers at *IBM* and *Nokia* began toying with the idea of marrying up jewelry form factor with a mobile phone [6]. From then on, articles and studies have been searching for the "best places" to position *wearable devices* (like *JawBone UP*[2a] bangle and *Nod*[2b] ring) on a body, overlooking rich history and cultural associations of *jewelry* [13], [14].

In the years, following publication of Wallace [5], Gaver [3], Seymour [11] and others about detrimental effect of the geek-factor and potential of enchanting objects (including *jewelry*) through technology, a number of jewelers once again began looking closer and experimenting with combining tech and jewelry. Nevertheless, not able to capitalize on the growing sophistication of technology, most of these creations were elaborate in their form, and basic on/off devices in their function.

Unsurprisingly, most consumers were not willing to accept neither jewelry-like gadgets as fashionable, nor couture and novelty *jewelry* as ready-to-wear adornment and useful devices. Since 2012 however, the floodgate was opened (*Figure 2*), and the *jewelry-like devices* are now being made for all sorts of applications. But with more and more silicon bangles entering the consumer space, it is not entirely clear if we are still creating gadgets that occupy the same body-parts as *jewelry*, or if we are beginning to fulfill the potential of enchanting our *jewelry* with technology.

[2] a) www.jawbone.com/up ; b) www.nod.com

Adoption of Wearables

Despite the growing hype, surrounding wearable devices and increase of their manufacturing output, the IDTechEx report, among others, indicated that majority of self-quantifying wearable gadgets end up in the drawer [4]. These observations are understandably causing growing concerns among the industry representatives, funding bodies and researchers of wearable devices. The general consensus is that the causes of the low adoption rates are ongoing issues surrounding data interpretation, business models, novel interfaces, battery consumption and miniaturization of component [12][8].

In addition to these factors, Duke-Woolley & Romeo point out that the current wearable market is disproportionally dominated by *Wellness* and *Sport & Fitness* market sectors, and that fostering growth of other *wearable* market sectors, like *Lifestyle Computing*, *Glamour* and *Communications*, could result in wider adoption [2]. However to achieve this, *wearables* would have to increasingly compete on the traditional fashion-market place, and their creators would have to engage fashion specialists, jewelers and retailers, as well as use existing supply chains and appeal to existing users of fashionable products.

Fashionable Wearables

The common point of view expressed in popular media is that current *wearables* largely appeal to people already engaged with technology, disregarding personal, generational and cultural factors. Despite the extensive influence of popular magazines (such as *Wired* and *Vogue*) on consumers, their criticisms are slow to percolate to the engineering and research communities. In the past few years however, a growing number of companies began to market their *wearable devices* as *jewelry*. Some, like *Nike+ FuelBand SE Gold*[3a] display fundamental misunderstanding of what *jewelry* is, receiving ambivalence from consumers and criticism from creative and fashion industries. Others, like *Ringly*[3b] and *Kovert*[3c] are questioned by tech reviews for cutting down number of features in their devices, but receive positive feedback from jewelers and fashionistas.

Research Aim

With the apparent dominance of silicone fitness and wellness tracking wristbands and rapid growth wearables, it is not clear what direction between *gadgets* and *jewelry* is being taken by creators of jewelry-*like devices* and what implications these directions are bringing. In this paper, we review market segments of *jewelry-like devices* and trends, associated with their target consumers, technical factors like I/O interfaces and connectivity. We then make observations of specific trends and propose possible directions that could facilitate collaborative development of *computational jewelry* and lead to wider adoption of the wearable devices.

[3] a) www.news.nike.com/news/new-nike-fuelband-se-metaluxe-makes-every-goal-golden ; b) www.ringly.com ; c) www.altru.is

METHOD

To achieve our research aim, we identified *wearable devices* that either looked like *jewelry*, or were marketed as such up to start of 2015. Devices range from completed projects (*Jawbone up24*, *Sesame*[4a], *Unpacking the Digital*[4b], etc.) to going through last stages of development (*MoodMetric*[4c], *ThumbTrack*[4d], etc.), to developed as concept or research prototypes as part of academic and/or creative endeavor (*IBM Digital Jewelry* [6], *Illumee*[4e], etc.)

Data Collection

The information was collected using *Google Chrome* web search and a vast variety of other sources, of which following selection is just a few: social media (*Pinterest*, *Facebook*, etc.); popular blogs and magazines on fashion, design and tech (www.wired.com, www.vogue.co.uk, www.thecoolhunter.co.uk, www.dezeen.com, etc.); design, user and industry events (*International Jewelry Show*[5a], *Wearable Technology Show*[5b], *Wearables London Meetup*[5c], *Collect*[5d], etc.); academic publications, available through *Google scholar* and *University of London* research libraries. The terms used for web and academic searches included, but not limited to: *wearables*, *wearable devices*, *computational/ digital/ smart jewelry* & *jewellery, pendent*, etc. Search ended when no new devices appeared.

Within all identified *jewelry-like* devices, we collected data on the year of announcement/ publication, market segments, target consumers, creators of form factor, types of interfaces, materials, and so forth. All collected data was aggregated into the spreadsheet (*Appendix A*[6]) and was analyzed, using descriptive statistical methods.

Categories & Classifications

Function categories were allocated in accordance with market sectors, proposed by Duke-Woolley & Romeo [2] (*Appendix B*[7]) with substituting *Glamour* sector with a wider used *Glamour & Fashion* sector. Output display categories were allocated based on standard sensory model. It is worth to note that occasional information relating to specific sensors, interfaces and connectivity was not explicitly stated by device creators. In these cases, missing information was marked as "unknown". *Jewelry designer* category encompassed practicing jewelers and product designers with strong jewelry sensibility (as evaluated by practicing jewelers). *Engineer/ designer* category encompassed device creators without jewelry background.

[4] a) www.ringtheory.com; b) www.digitaljewellery.com/jaynewallace/unpicking_the_digital_lockets.html c) www.moodmetric.com; d) http://bit.ly/1JUOVqr; e) http://dl.acm.org/citation.cfm?id=2495970

[5] a) www.jewellerylondon.com; b) www.wearabletechnologyshow.net ; c) www.meetup.com/wearables-london/; d) www.craftscouncil.org.uk

[6] www.yuliasilina.com/overview-of-jewelry-like-devices.html

[7] www.beechamresearch.com/article.aspx?id=20

AN OVERVIEW

In this section we give an overview of the *jewelry-like devices*, based on review and analysis of 187 devices, identified before February 14, 2015 (*Appendix A*). Over 75%, i.e. 145 of all reviewed devices were developed in the past few years, which is reflected by the sharp spike following 2012 (*Figure 2*).

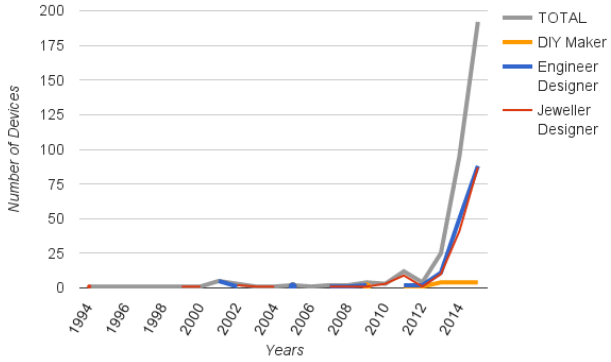

Figure 2 Timeline of jewelry-like devices

Well over a half, i.e.116 of the reviewed devices was executed as part of the commercial project, with the remainder split between academic research and creative endeavors (*Figure 3*).

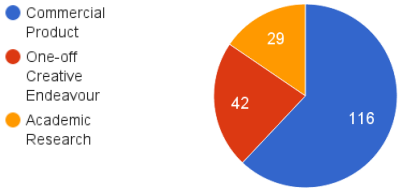

Figure 3 Project categories of reviewed devices

Near three quarters, i.e. 140 of the reviewed devices were completed or were undergoing final stages of developments, often following crowd-funding campaign. Remainder of devices was either theoretical or working prototypes (*Figure 4*), largely developed before 2012.

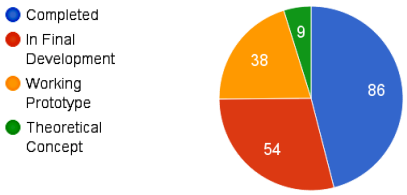

Figure 4 State of completion of reviewed devices

Types of Jewelry-like Devices

Traditional analogue *jewelry* takes numerous forms, adoring every visible and intimate part of body, depending on culture and fashion. Despite this variety, disproportionate 40% i.e. 75 of the *jewelry-like devices* currently fall in the limited category of bracelets (*Figure 6*). Interestingly, almost of half of these are bands, created by *engineer/ designer* (*Figure 11*).

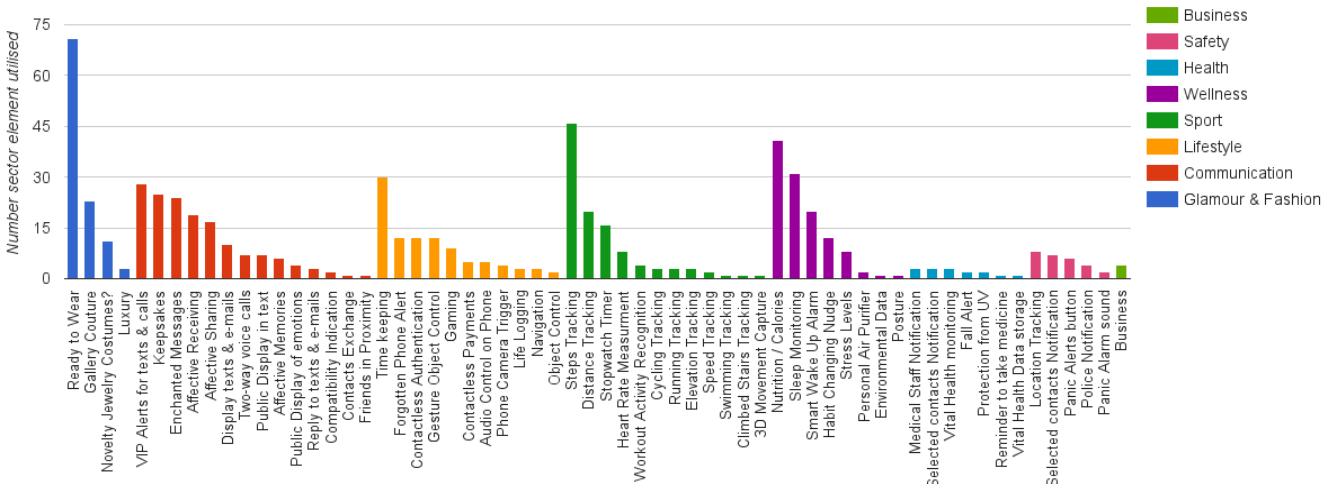

Figure 5 Detailed breakdown of functions in market sector categories

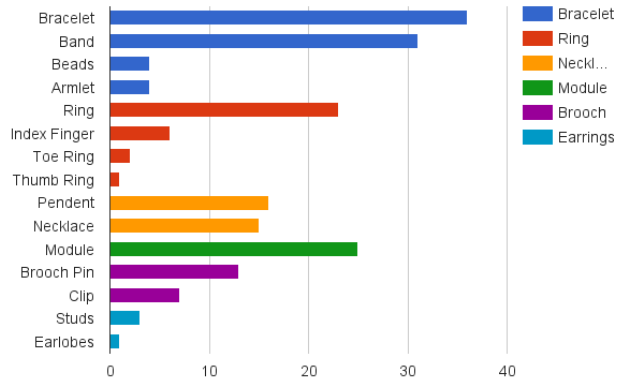

Figure 6 Types of reviewed devices

Market sectors

As with other categories, discussed in the following sections, many individual *jewelry-like devices* inhibit more than one market sector. In fact, only 64 of reviewed devices were part of a single sector (*Figure 7*). And even among these, the devices had multiple functions (*Figure 5*).

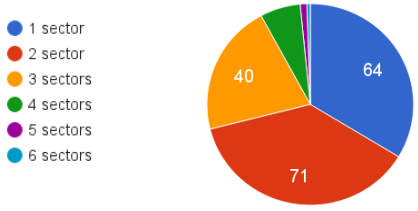

Figure 7 Devices with multiple market sectors

Glamour & Fashion sector was represented in 107 devices, constituting 57% of all reviewed devices (*Figure 8*) and was often combined with one or more of other sectors. *Wellness* and *Sport & Fitness* sectors are often appear together, so do *Communication* and *Lifestyle*.

Form Factor

All of the reviewed *jewelry-like devices* that belonged to *Glamour & Fashion* user sector could be considered

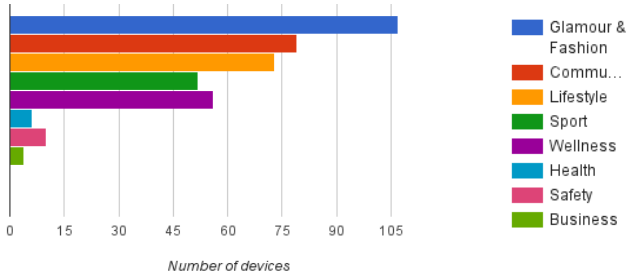

Figure 8 Market sectors represented in reviewed devices

fashionable *computational jewelry*. Few, i.e. 11 of devices were prototypes did not provide information on their potential form factor, and were excluded from graphs that compare features of *jewelry* and *gadgets* (*Figure 9*).

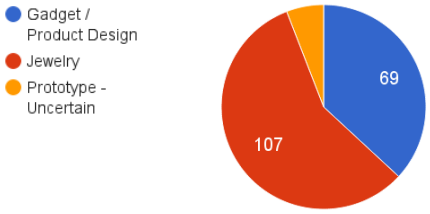

Figure 9 Form Factor of the jewelry-like devices

Unlike *gadgets*, that were predominantly designed to be unisex, large proportion of *computational jewelry* was created for women, reflecting consumer base of analog jewelry (*Figure 9*). Almost all devices with a form factor of *computational jewelry* were created by jewelers or designers with *jewelry* sensibility. Unsurprisingly, none of the gadgets were designed by jewelers (*Figure 11*). Similarly, majority of the gadgets were made using materials, common in product design, such as silicone, alphanumerical screens and utilitarian plastics. In contrast, *computational jewelry* devices were made using materials common in *jewelry*, such as stones, metals, leather, decorative plastics etc. (*Figure 12*).

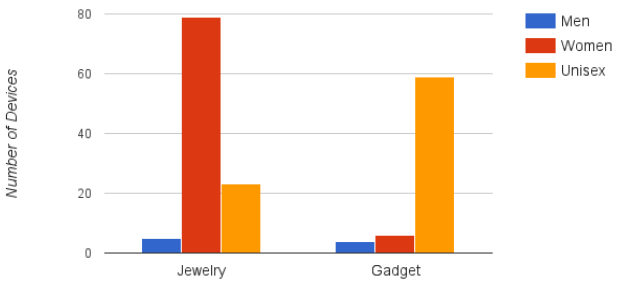

Figure 10 Consumer base

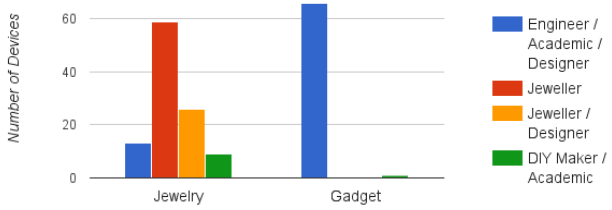

Figure 11 Creators of form factor

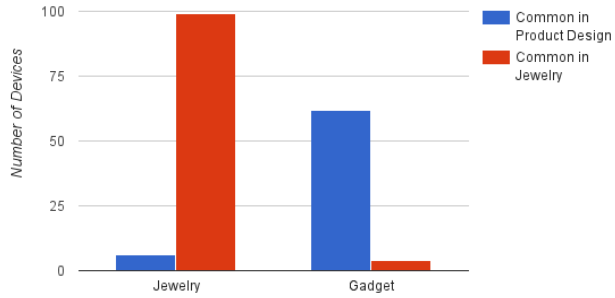

Figure 12 Materials used in devices

Technical Factors

As with market sectors, reviewed *jewelry-like devices* have more than one input origin to serve different functions. These generally comprise out of active inputs by the person (international button, touch etc.), background data collection from person (biometrics, accelerometer, etc.), environmental sensors (pollution, humidity, etc.) and input from the external device (paired devices, NFC & Bluetooth readers, prototype computer connection, etc.) (*Figure 13*).

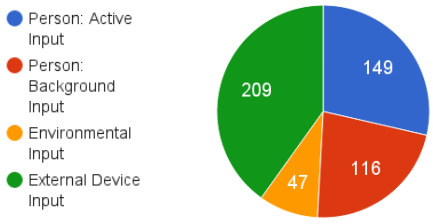

Figure 13 Input origins present in devices

Vast majority, i.e. all but 22 of reviewed *jewelry-like devices* have multi-modal output with some forms of visual display and external data collection (*Figure 14*). Whereas Visual and Tactile displays are the most common outputs, it is worth to point out that these categories are broad and have different aesthetic and emotional properties. As a result, individual modalities within these forms of displays are used differently in *jewelry* and *gadgets*.

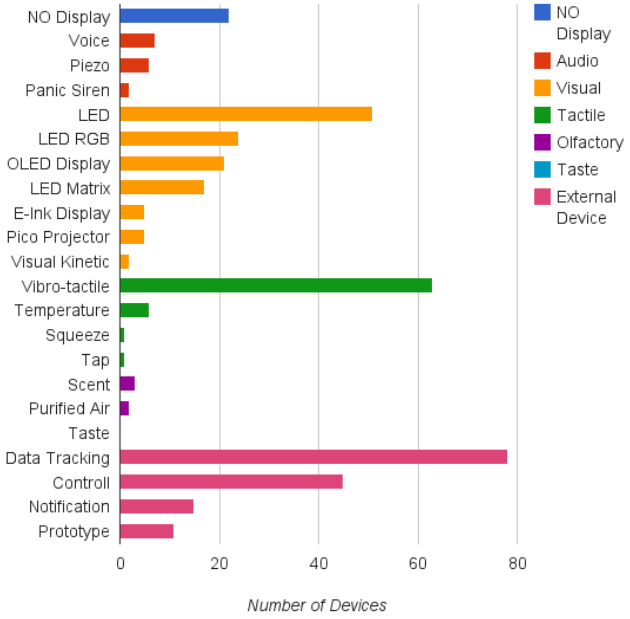

Figure 14 Output Displays

Similarly to other forms of wearable technologies, the taxonomy indicates that *Low Energy Bluetooth* (BLE) is overwhelmingly the most popular form of connectivity for *jewelry-like devices*, providing communication to 69%, i.e. 125 of all *jewelry-like devices* (*Figure 15*). Near a quarter, i.e. 40 of *jewelry-like devices* are standalone. It is worth to note, that many of these were developed as one-off Fashion-only pieces by jewelers without collaboration with engineers.

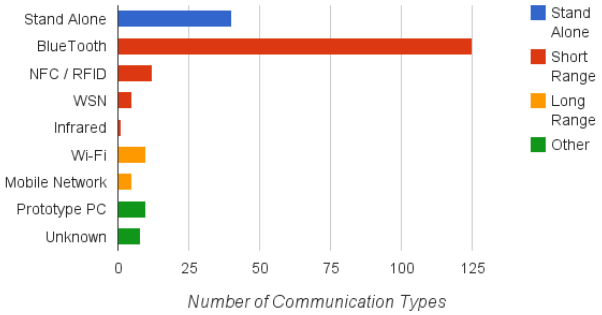

Figure 15 Means of communication with device

Over a half, i.e. 106 of the devices are paired to *Apple* and/or *Android* smart phones and are controlled or accessed either through the APP or website. However majority, i.e.153 of the devices also had some level of control and information viewing from variety of displays (*Figure 17*). 118 of the devices contain batteries that require a form of charging. However, a third, i.e. 52 of the devices was powered by replaceable (often coin) batteries (*Figure 18*).

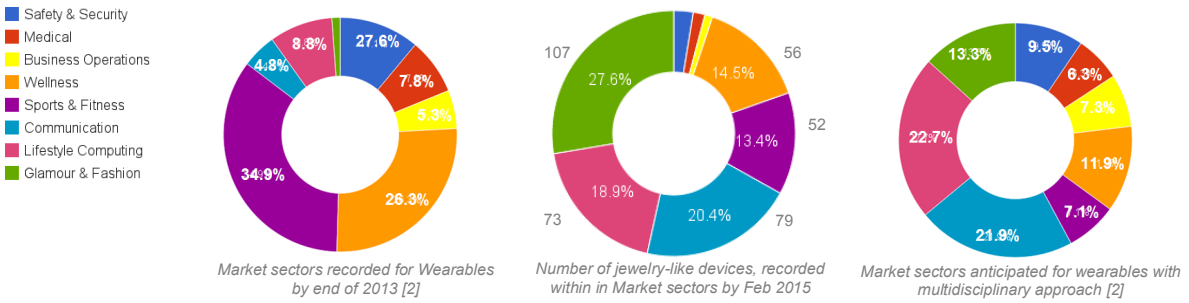

Figure 16 Shift in the Market Sectors

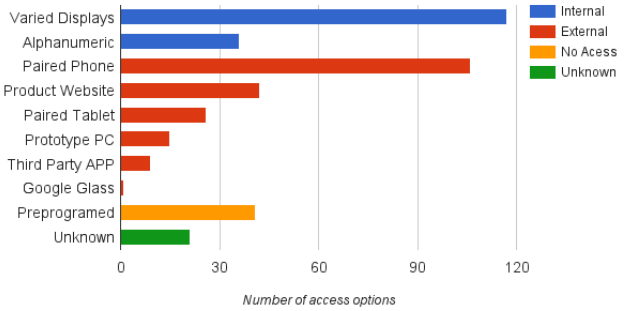

Figure 17 Information access from the device

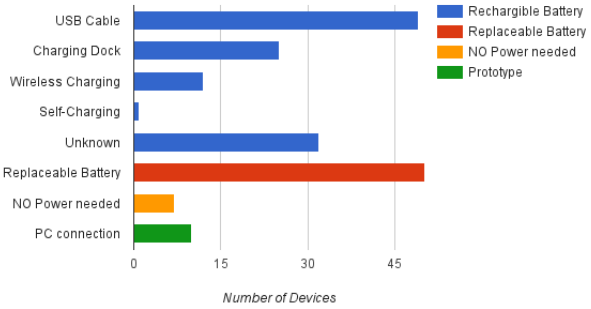

Figure 18 Power & charge

DISCUSSION

Defining the Form Factor

It is worth remembering, that although *computational jewelry* is subset of *jewelry-like devices*, it is a fashionable adornment artifact that function both as a computational device and as *jewelry*. Although we found some occasional exceptions, like *Intel*'s *MICA Bracelet*[8], the general trend in our overview suggested that if the device is a silicone band or has alpha-numeric display, it does not have the form factor of *computational jewelry*. Thus, *gadgets* like these ought to be excluded from *computational jewelry*. It is also questionable whether simple stand-alone on/off pieces, created by jewelers like *Nicolas Estrada*[9] could be considered *computational jewelry*, as they lack computational element.

Eliminating *gadgets* and non-computational *jewelry-like devices* brings types of *computational jewelry* in line with trends for the analogue *jewelry* in most types of *jewelry*. Though earrings, body piercings and so on may have to wait until further miniaturization of components.

Shift in Market sectors

The analysis of our review indicates that market sectors of *jewelry-like devices* are already making a shift, anticipated by Duke-Woolley & Romeo [2] (*Figure 16*). Looking at the *computational jewelry* alone, the shift is even more dramatic. It is understandable that *Security* and *Business* sectors might lag in the adoption of *computational jewelry*. Both of these sectors are largely utilitarian and lay outside of the realm of the personal adornment and self-expression. But it is disappointing to see that *Healthcare* market sector is not benefiting from *computational jewelry* as a form factor for the devices that are used by patients in their daily life.

Accepting Multidisciplinarity

Wallace [15], made a comprehensive criticism of gadgetry and benefits of collaboration with jewelers on creation of *computational jewelry*. Seymour [11] went a step beyond, providing a much needed practical guide, linking creative fashion and engineering communities. Nevertheless, our overview demonstrates that although jewelers understand the market, consumers and historical context of adornment and *jewelry* use, until recently they were able to create simple on/off devices, missing out on the potential of computational technology. On the other hand engineers and to some extent product designers, often misunderstand the core requirements surrounding *fashionable technology*. The examples of *Misfit Swarowsky Shine*[10a], *Cuff*[10b], *FitBit Tory Burch*[10c], *Unpicking the Digital,* and others clearly demonstrate that

[8] www.intel.com/content/www/us/en/wearables/fashion-technology.html

[9] http://klimt02.net/jewellers/660

[10] a) http://store.misfit.com/collections/swarovski-shine ; b) www.cuff.io ; c) www.fitbit.com/uk/toryburch#1

most fruitful aesthetical and technological pieces occur when engineers and jewelers collaborate.

Revisiting Materials

In contrast to numerous precious and semi-precious metals, gemstones, woods, shells and other materials traditionally used in jewelry and a vast variety of contemporary materials, the materials that we identified in current *jewelry-like devices* are but a poor shadow. From wedding rings, to bracelets and earrings, analog *jewelry* has been worn by users continuously twenty-four hours a day. And there is no reason to think that "silicone", which we recorded in use in so many *gadget jewelry-like devices*, is a superior solution for all such applications. This is particularly true when creating desirable objects that expresses personality of its wearer.

This is not to dismiss potential of new materials. *Purple*[11a] and *Looksee*[11b] clearly demonstrate that it is well worth looking at gadget-associated materials through the eyes of a *jeweler* rather than a product designer. Furthermore, surfaces with capacitive touch improve and enchant the interaction with the *jewelry*. Similarly color-, odor-, temperature- and shape-shifting materials need to be looked at closer as they have immense potential to augment our experiences and bring new dimension to communication through *jewelry*.

Expanding Interaction Modalities

One of the more interesting aspects of *computational jewelry* is its potential for interactivity and enchanted functionality. But our overview of the *jewelry-like devices* suggests disproportional use on narrow band of visual modalities, like alpha-numeric screens and LEDs. This could be because it is not uncommon in engineering and product design to view the visual displays under one umbrella, regardless of their aesthetic and emotional qualities.

Recognizing the association of screens and LEDs with gadgetry, many *jewelry-like devices* are beginning to conceal them. There is also a noted shift in using vibrio-tactile modality in *computational jewelry* where the motor could be hidden behind materials suitable for *jewelry*. But in many ways these trends serve as manifestation of underexplored state of novel modalities for output displays, rather than a long-term solution for reducing visual gadgetry.

Clarifying Consumer Base

As with the user sectors, consumer base of the *jewelry-like devices* is shifting. It is telling that a large proportion of *gadgets* in reviewed *jewelry-like devices* created by engineers and product designers to be unisex. And that devices created by jewelers are created for female audience, reflecting trends in analogue *jewelry*. Larger companies like *Intel*, *FitBit* and *Misfit* began investigating gender preferences of their consumers. Predictably, the discovered that though is not uncommon to see young men wearing jewelry in the diverse urban setting, current cultural trends clearly indicate that prevailing consumers of *jewelry* are women of all tastes and ages.

Curing Featuritis

Several smaller start-ups independently made an interesting, if somewhat obvious observation that women customarily keep their phones in the bags rather than in the pockets. Consequently, leading *computational jewelry* like *Ringly*, *Kovert* and *Cuff* are focused at female users who would subtly receive alert notifications on their *jewelry* about incoming calls and VIP messages coming from their phones.

In contrast with the trends in *gadgets* that are packing more and more features into a single device, *Ringly*, *Kovert* report that their focus groups were interested in single feature: notification. The main requirements were that the feature works well and the end-product looks and feels like *jewelry*. Similarly, the *Artemis*[12a] was made just for panic alert notifications, and *Tactilu*[12b] just for affective connection with loved-ones.

Liberating Connectivity

Provided that the phone or other paired devices are in close proximity to *jewelry-like device*, BLE is a widely used solution for connecting them to the cloud. To liberate *computational jewelry* from this dependency, it might be worth following early examples of *MICA Bracelet* and look at solutions integrating connectivity through the use of mobile networks. This however, brings along a plethora of new challenges in both business models and technology.

Power without Wires

One of jewelrs pointed out in an informal conversation that "an engagement ring may have strings attached, but it does not have any wires sticking out of it". If the *jewelry-like devices* are to become *computational jewelry*, discrete and integrated powering solutions need to be adopted. Some companies like *Cuff* and *Stiletto*[13], are implementing an elegant solution, by placing a wireless charger pad in a jewelry box and charging *jewelry* wirelessly. Others like *Misfit* and *JawBone UP Move Clip* rely still on a simple solution of replaceable battery, eliminating the inconvenience of daily charging.

Transferable Tech Module

Informal conversations with the jewelers indicate that those of them interested in wearable technology are

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[11] a) www.artefactgroup.com/content/work/purple-a-wearable-locket-for-the-21st-century/ ; b) www.lookseelabs.com/#infinitepossibilities

[12] a) www.artemisfashion.com/press/artemis-primary-product-photo-square/ ; b) www.tactilu.com

[13] www.stiletto.is/collections/all

feeling limited by available technological forms of expression and are overwhelmed by the barriers, created in multidisciplinary collaborations. Recent publications by Rose [9] and Ryan [10] further demonstrate that the conversations about collaboration between disparate communities and debates about emotional enchanted user experience are still ongoing.

A promising way to resolve this conundrum may lay in use of technology modules, by likes of *Misfit* and *Cuff* that can be transferable between different pieces of *jewelry*. Already, *Rebecca Minkoff*[14] created an alternative housing for *Fitbit* module, and there are some indications that this trend might progress, in a similar way as covers for mobile phones did.

Making their transferable module into a feature "stone", *Kovert* eliminated the need to hide it. Further standardizing these modules (in the same ways as cuts for gem-stone, metal alloys and material thicknesses are standard throughout *jewelry* industry) will allow any jewelers with or without knowledge of technology to create *computational jewelry* that is both beautiful and functional and upgradable over time.

FUTURE WORK

As field of *computational jewelry* expands, we intend to continue observing and tracking developments and shifting trends, surrounding *jewelry-like devices*. Progress around transferable modules, I/O modalities and futurities are of the particular interest. Among other questions, it would also be fascinating to understand what might begin to happen with *computational jewelry* when technology within will become discontinued or upgraded. Will the devices be made to be disposable, like seasonal consumer fashion? Would technology become transferable and standardized, as sizes of stones and sheet metals are? Or would these devices be made as heirloom pieces that could function as adornment even when technology is absolute?

CONCLUSION

In this paper, we reviewed and analyzed 187 *jewelry-like devices* in order to capture emerging trends and make recommendations for enhancing this exiting field. Over a half of the reviewed devices could be considered to be pieces of fashionable *computational jewelry*. These pieces belong to *Glamour & Fashion* market sector, but may cover additional sectors. The form factor of these pieces is predominantly devised by jewelers and made out of materials common in *jewelry*, rather than in product design.

Following the overview of *jewelry-like devices*, we emphasize that the consumer base of these pieces largely consists of women with different tastes and age groups. We point out that the excessive features in these devices may need to be revisited to accommodate needs of this user group. We further emphasize that interface modalities and novel materials are underexplored and provide suggestions on charging solutions and connectivity. We then note that use of transferable modules is a promising solution for streamlining multidisciplinary collaborations in creation of *computational jewelry* that may facilitate wider adoption.

[14] www.rebeccaminkoff.com/rmedit/2014/09/going-wearable/

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