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Making Sense of Human-Food Interaction

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ABSTRACT

Activity in Human-Food Interaction (HFI) research is skyrocketing across a broad range of disciplinary interests and concerns. The dynamic and heterogeneous nature of this emerging field presents a challenge to scholars wishing to critically engage with prior work, identify gaps and ensure impact. It also challenges the formation of community. We present a Systematic Mapping Study of HFI research and an online data visualisation tool developed to respond to these issues. The tool allows researchers to engage in new ways with the HFI literature, propose modifications and additions to the review, and thereby actively engage in community-making. Our contribution is threefold: (1) we characterize the state of HFI, reporting trends, challenges and opportunities; (2) we provide a taxonomy and tool for diffractive reading of the literature; and (3) we offer our approach for adaptation by research fields facing similar challenges, positing value of the tool and approach beyond HFI.

CCS CONCEPTS

• **Human-centered computing** → *HCI theory, concepts and models.*

KEYWORDS

Human-Food Interaction, Literature Review, Scientific Mapping Tools, Data Visualization

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1 INTRODUCTION

The dynamic and heterogeneous nature of HFI as a field presents a challenge to scholars wishing to critically engage with prior work, position their research in context, identify gaps and ensure impact. We therefore decided to undertake a comprehensive review in the form of a Systematic Mapping Study (SMS) [10].

Our SMS began with data collection. The aim was to create a comprehensive dataset of scientific publications, to better understand the scope of HFI. Reviews, both within and beyond HCI, often use computation to collect publications automatically from online repositories [16]. Relevant examples include a visual analysis approach to update systematic reviews [28] and a framework for conducting reviews through web scraping and data clustering [49]. Automated scraping of data from digital repositories is a useful technique when the scope of a research field can be determined, and data points categorized through a solid rationale. Unfortunately, this was not possible in HFI.

HFI is an emerging research field that is remarkably dynamic and heterogeneous. It cuts across numerous research disciplines and is approached from varied perspectives, reflecting the diversity of ways that people interact with food. Because of this diversity, we struggled to determine where an algorithm should search for HFI publications and what

exactly it should look for. We knew the ACM database includes HFI-related publications. We also knew we would find important publications elsewhere. Despite concerted effort, without a comprehensive dataset, we were unable to develop a solid rationale to categorize data points algorithmically and we failed to formulate a thematic structure to organize the not-yet-gathered, burgeoning dataset. We were also unable to find an existing framework of HFI that might help us. We therefore decided to build a comprehensive dataset and develop a structure for categorisation using a fully manual method, following Bar-Ilan and Aharony [7].

To build the dataset, we began with a keyword, title and abstract search of 'food' in the ACM database. We manually filtered the first 700 results, to guard against repetition and exclude papers we determined did not belong. We then added texts from other sources, based on author knowledge and appearance in references. The first author has experience as a designer and researcher in gastronomic restaurants. The last author's research cuts across Design, HCI and Science, Technology and Society Studies (STS). Together, they share a long-standing interest in food design and experimental food practices. This diverse experience enriched our understanding of where to look for sources and enabled us to compose a dataset that includes papers from a broad spectrum of venues and repositories. This approach required careful negotiation to determine fit and pointed to a need to validate determinations with the research community. The resulting dataset—before external evaluation—consisted of 260 publications, most published since 2009 (Figure 1).

In this paper we report the emergent process and outcomes of our SMS. Our contribution is threefold: (1) We characterize the current state of HFI to empower interested researchers to better position their work and find new opportunities for impact. (2) We provide an online data visualisation tool to allow the research community to dynamically update our review, and thus engage actively with the dynamic and heterogenous nature of HFI. (3) We propose our process and tool for adaptation by other, equally fluid, emerging fields of research that struggle with similar issues. We thus posit value for our process and tool beyond HFI.

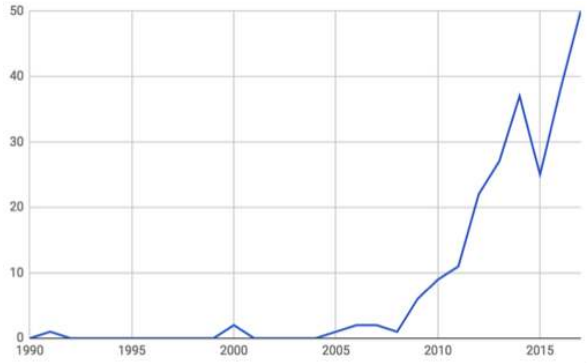

Figure 1: HFI publications per year, using our initial dataset.

2 DATA ANALYSIS

We began our analysis using a combination of quantitative and qualitative methods, inspired by Halskov and Hansen [31]. We first examined two quantitative variables: publication *year* and *venue*. The results confirmed our impression that the research space of HFI is not only emergent, but can be characterised by radical growth (see Figure 1). Our analysis also indicated remarkable heterogeneity. The first dataset includes papers across 76 different venues. A variety of disciplines, foci of interest and methodological approaches are represented, including: cross-modal psychology (e.g. [59]), engineering (e.g. [37]), computer science (e.g. [47]), HCI (e.g. [43]), speculative design (e.g. [25]), and more. Further, we found that a significant number of papers are disseminated through workshops and Special Interest Groups (SIGs).

We also identified three growing communities within HFI. The *Food CHI* community originated in 2017 as a SIG [36] and was maintained in 2018 as a conference workshop [26]. It extends previous attempts at community-making around food and interaction design (e.g. [17, 18]). Examples of research in this community include: Choi et al.'s edited collection of CHI research into eating, cooking and growing food [13], Dolejšová and Kaiying's research that encourages citizens to co-design DIY food-related technologies [24], and Khot et al.'s 3D chocolate print system that offers users personalised 'activity treats' after exercising [39].

The second community, *Multisensory Human-Food Interaction* (MHFI), has been gathering in workshops since 2016 (e.g. [50, 63]). Well-cited research from this community includes: Obrist's account of multisensory interfaces [51] and Spence's *Gastrophysics* investigations of the impact of multisensory phenomena on people's eating behaviour [58].

The third community seems less cohesive. Since 2012, computer scientists have discussed AI approaches to HFI at a variety of workshops, including *Cooking with Computers* [20, 21], *Multimedia Cooking and Eating Activities* [1, 2, 36], and *Multimedia Assisted Dietary Management* [3]. Examples of papers from this community include: Hashimoto et al.'s multimodal method for recognizing ingredients in food preparation [34] and Mori et al.'s machine learning approach to recipe text processing [44]. Although few researchers participate across all of these workshops, our analysis suggests a strong connection across the research concerns. We thus consider them a distinct community.

According to our initial dataset, researchers connected to these three communities are among the most active in HFI; the HFI community tends to advance in sub-communities

gathered around workshops and SIGs, with little crossover between the three communities.

Following a quantitative analysis based on publication year and venue, we conducted a qualitative analysis of the data. Our aim was to identify affinities and differences, spot trends and unexplored opportunities. To ground our analysis, we intended to use a theory informed approach to categorise the data [31]. Yet, HFI is such a new field that we could not find a community-accepted theoretical frame to follow. We needed a clear, transversal set of criteria to map the publications and thus characterize the field beyond the surface. We therefore developed a taxonomy from the data itself.

3 A CONCEPTUAL MODEL OF HFI RESEARCH

Taxonomies simplify complex realities. While their use implies a compromise on nuance, they afford a structure to make sense of data that would otherwise be difficult to grasp. The rationale behind our taxonomy was shaped by a need to (1) embrace the diversity of perspectives included in the HFI publication dataset, and (2) reflect contemporary issues in HCI, such as the multiplicity of roles of technology in human life [33] and the balance between automation and individual empowerment [38]. This was an emergent process: as we engaged the data in more detail, the coding evolved until we arrived at the taxonomy. The result includes three lenses through which HFI publications can be analysed:

Focus affords positioning of HFI papers on a continuum between functionality and experience, where the latter is divided across individual experience and social bonding. This lens responds to the variety of purposes we found in the dataset. For example, eating monitoring systems seem to be viewed as functionality-oriented artefacts with a clear instrumental role (e.g. [67]). In contrast, Multisensory HFI contributions often focus on augmenting individual experience of food, e.g. through sound stimuli [62]. Differently, many speculative works propose food as a platform for social bonding, supporting and augmenting social interaction around food practices, e.g. digital food sharing [56].

Agency refers to the interplay between humans and technology when dealing with food. To represent the diversity of approaches to agency we found in the dataset, publications are attributed a position on a continuum between person and technology, depending on how the researchers themselves determine that their work attributes agency. On one end of the spectrum, we find artefacts that perform food-related tasks with a high degree of autonomy from humans. For example, a pair of eyeglasses that track chewing to monitor eating activity without user input [68], or a recipe-generation algorithm [47]. On the other end, we find contributions that empower humans to conduct food-related practices themselves; for example, an exploration of food democracy in local food networks [54], or a study of user experience in user-managed food journaling systems [19]).

Domain responds to the diverse nature of human-food relationships, present in many areas of life, by enabling categorisation of research in relation to the human-food web. A first pass at the data identified seven domains: source, store, produce, eat, identify, waste and track. A closer read led us to conflate 1) store and waste, and 2) identify and track, as we noted they were often handled interchangeably. We also added 'speculate' to represent speculative research that did not clearly fall into other domains. The final lens proposes 6 categories to classify HFI contributions:

- *Source*: foraging or buying food (e.g. [35, 41]).
- *Store*: practices of both storing and disposing of food (e.g. [27, 52]).
- *Produce*: growing foods, as well as manipulating them to create more complex combinations, such as dishes or meals (e.g. [64, 69]).
- *Track*: identification and measurement of food and food practices (e.g. [42, 46]).
- *Eat*: food consumption (e.g. [57, 60]).
- *Speculate*: contributions that explore alternative food futures, or conduct meta-reflections on HFI as a research field (e.g. [12, 24]).

Analysing our Dataset Through the Taxonomy

Using our three-lens taxonomy, we manually sorted the 260-publication dataset. For each publication, we determined a position in the focus and agency continuums and a single domain, based on our interpretation of the text. Each publication was coded by one researcher, then validated or contested by another. In case of disagreement, we negotiated which code to attribute. To ensure the dataset was robust, we shared our coding publicly and offered first authors the chance to contest our analysis. We received and actioned 8 requests for changes, including allowing multiple domains per publication (see *Community Validation* section for more). The taxonomy helped us bind together contributions with radically different perspectives and compare papers that we previously struggled with. A first read of the data through the conceptual model provided the following insights:

Functionality vs. Individual Experience vs. Social Bonding. The majority of HFI publications focus on functionality, with less emphasis on experiential aspects of food practice. Within experience-related contributions, there is more emphasis on individual experiencing of food practice than on social bonding (Figure 2, left).

Technology vs. Person. Contributions that give greater autonomy to the technology rather than the person using the technology are more numerous than those that empower

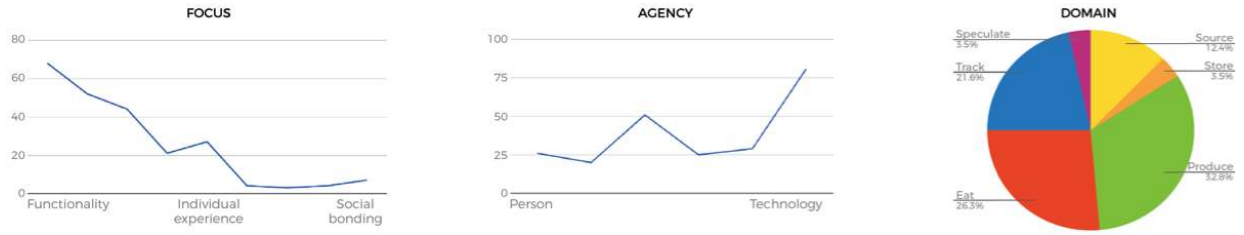

Figure 2: First findings across three lenses (*l-r*): Focus, Agency and Domain. In Focus and Agency, the x-axes represent number of papers and the y-axes include intermediate steps between categories to afford more nuanced interpretation.

humans to impact their personal food practices (Figure 2, centre). Speculative HFI works counter this trend.

Unequal distribution of concerns. Papers that focus on food production (32,8%), eating (26,3%) and tracking (21.6%), dominate. Sourcing (12.4%) is also relatively well explored, compared to storing (3.5%) and speculating (3.5%), which seem of little interest to the HFI community to date (Figure 2, right).

At this point, our dataset contained 260 data points, categorized through three lenses, including meta-data such as author keywords, publication year, venue and type. This number of variables was challenging to manage without automation. To facilitate more in-depth readings of the dataset, we decided to develop an interactive data visualisation tool. The aim was to leverage the potential of computation to visually map the data according to our conceptual model, taking the meta-data variables into account. In the next section, we describe the tool and examine how it extends previous works on data visualisation for literature reviews.

4 DATA VISUALISATION TOOL

The use of data visualisation to characterize research fields is not new. Data visualisations enable viewers to make sense of datasets that would otherwise be difficult to parse. When interactive, they afford personalised queries, and thus more in-depth and succinct analyses. Previous systematic mapping studies that leverage this technique include: a visualisation of the evolution of technical games research [48], a tool to support the review of HCI and InfoVis literature [53], a system to visualise research trends in conferences [40] and an interactive characterisation of the state of the art in visualizing dynamic graphs [11]. Inspired by these examples, we designed an online tool to allow dynamic visualisation of our dataset using the HFI taxonomy. The resulting tool gives access to the dataset, and the possibility to edit or propose additions. It affords personalised readings of the data, using filters to shift perspectives or view everything at once. A researcher can thus gain a general overview of the state of HFI research, or focus on different perspectives as they target their analysis.

Figure 3 provides a snapshot of the tool interface, with all filters selected and thus all publications visible. Papers are represented as coloured dots on a graph. The filters, available on the right, include: domain, focus, agency, publication year, venue, keywords and type (e.g. journal article, full conference paper, extended abstract, book, etc.). Each publication-dot visualises domain through colour, focus through positioning on the horizontal axis, and agency through positioning on the vertical axis. Dots can be selected to view the associated citation, abstract and keyword information below the visualisation area.

Our tool—which we are calling the *HFI Lit Review App*—enabled us to quickly and easily verify emerging trends identified during desk research. This capability was significant, as our findings were somewhat intuitive when manually-comparing 260 data points. When visualised using the HFI Lit Review App, we could quickly determine if trends held across the data. We could also identify trends that were previously not visible. For example, contributions in the domain of tracking strongly tend towards technology along the agency continuum, and in the domain of eating towards individual experience. While, on the surface, these trends may not be surprising, it is useful to see it in the data. The visualisation makes apparent opportunities to expand areas of research towards, for example, supporting increasingly social interactions through food.

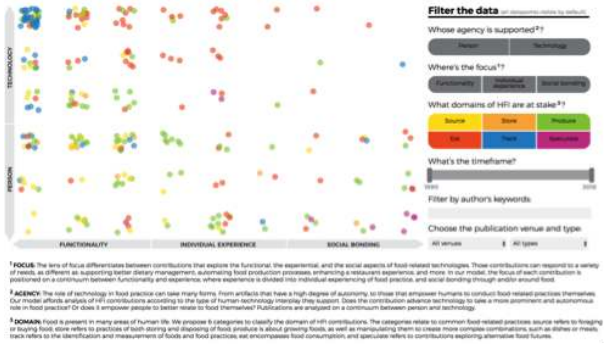

Figure 3: First iteration of the HFI Lit Review App.

Because of the dynamic nature of HFI research, the HFI Lit Review App will only be useful if it is up to date, and if there is consensus on how content is represented. We therefore set up the app like a wiki, with guidelines to ensure a robust dataset. Readers can suggest modifications and additions, challenge existing interpretations of data, and contrast their own and others' perspectives on research. Proposed changes are monitored by a committee, currently made up of the authors. The committee defers to author requests, and opens up for discussion proposals made by others. This inbuilt opportunity for discussion is meant to stimulate fruitful dialogue within the HFI community. The intention is to empower scholars to collectively build and maintain a shared repository of publications across the diverse approaches to HFI. If successful, it will allow the app to become an evolving platform and locus for community-driven sense making.

Data visualizations for systematic mapping studies are typically automated: they often rely on computation to collect, analyse and represent quantitative data. However, there is more than one way to understand data [55], and in a field of research as heterogeneous as HFI differences of perspective bring added value. We therefore designed the app to enable diffractive reading. As [8, 9] explains, (building on [32]) diffractive reading maps interference, not replication, reflection or reproduction: not where differences appear but rather where the effects of difference appear. By making differences visible, diffraction affords rapid and easy identification of research opportunities. As we discuss below, our experience suggests that diffractive reading of the data better positions researchers to challenge their assumptions and embrace other perspectives.

Critically, our tool relies on human interpretation—interested researchers can contribute, and thereby help make sense of HFI. As they read the data, they can change filters to gain differing perspectives to understand other researchers' points of view. This combination of human interpretation and computational visualisation is a key characteristic of the app. It enables the construction of a more comprehensive dataset and facilitates closer, more nuanced reading of the data. Our tool allows researchers to engage with a dataset of literature that has been, and continues to be, categorised and updated by the broader HFI research community. We believe this approach has great potential in any field where radically diverse perspectives coexist. As we discuss in the next section, community response, to date, has been enthusiastic.

5 COMMUNITY VALIDATION

To ensure our work reflects the diversity of perspectives within HFI, we needed to validate our taxonomy and expand the dataset in consultation with community. We also needed to confirm whether researchers across HFI saw value in our tool, and if they would be willing to use and maintain it.

Methodology

Our community validation strategy involved two phases: First, we opened up our provisional work for comment at the 2018 ACM Designing Interactive Systems conference (DIS'18) [4]. Second, we contacted the first authors of each publication in the dataset by e-mail (except where contact emails were missing or invalid). Both actions were framed as an invitation to comment on our approach and propose modifications to the taxonomy, app and dataset.

DIS'18 Poster presentation. During the DIS poster session, we held semi-structured conversations with 15 interested researchers, using the following tangible conversation tools [15] to elicit constructive comments:

- A working version of the HFI Lit Review app on a laptop, that researchers could test in-situ.
- Thirteen printed papers from the dataset, that participants were invited to review. The papers were chosen for their diversity, and because we had found them challenging to categorise. For example, we struggled to determine the domain of an artwork that explores the human food system [22], and to position along the agency continuum a system to create programmable taste structures [69]. We hoped that (re)categorization

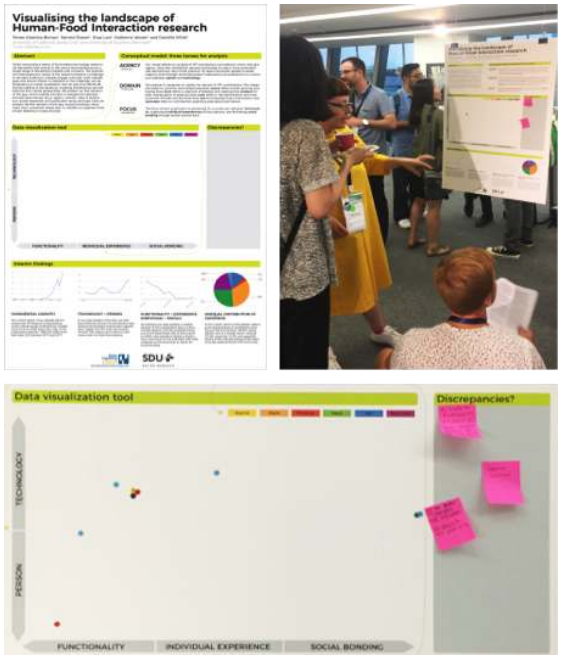

Figure 4: Community validation at DIS'18. Top-left: poster. Top-right: researchers engaging with an analogue version of the tool. Bottom: analogue contributions by participants: dots placed on the matrix and sticky note comments.

of these publications by other researchers might provide a useful challenge to our conceptual model.
- A poster, including the empty data visualisation framework (Figure 4, top left), that researchers could fill in and comment on. The poster included the citation and abstract of the accompanying publication [5], available on the ACM database (at this point without a paywall).
- Colored sticker dots and sticky-notes that could be placed onto the poster, as well as pens, markers and papers for further comments.

E-mail correspondence. We sent an e-mail to all first authors in the dataset, offering them a chance to give feedback and challenge our analysis of their work. The e-mail included:

- A short description of our research and motivations, and a link to the work-in-progress publication [5].
- A direct link so they could easily suggest changes to our analysis of their publication(s) in the dataset.
- Four questions asking for feedback about the tool: *Are the filters we chose working for you? Is anything missing that you consider critical? Should something be changed? Once it's finished, do you think it will be useful for you or for other researchers working in this space?*

At the time, the dataset included 260 publications. A number of authors had more than one paper, the maximum being 9. We accessed 129 active e-mail addresses of 212 first authors included in the dataset.

Results

We received feedback from 26 respondents in total: 15 at DIS'18 and 11 through email. 7 authors—4 via email—used the app to re-interpret the categorization of their research. One author reinterpreted their work manually (at DIS'18). We used thematic analysis [30] to examine this feedback. We organise our findings here in four themes: the online tool, the dataset, our analysis and the conceptual model.

Online tool. All 26 respondents expressed enthusiasm towards the potential of the HFI Lit Review tool: 'I am very glad to know that someone has thought about creating a database for HFI' (R8, e-mail), and: 'I definitely think it would be useful' (R7, e-mail). Some respondents said they struggled to position their work and find opportunities for future research when navigating HFI literature: 'I've been doing a review of the HFI works for one of my thesis chapters now, and it's tricky, right. What is HFI anyway?' (R3, e-mail). A number of researchers suggested that the tool could be useful beyond HFI, pointing out that the combination of computational visualisation and human interpretation, with a custom taxonomy such as we created, might help characterize other emerging fields within HCI., e.g. Animal-Computer Interaction. Another researcher (at DIS'18) noted that such a tool would be useful for PhD candidates working at the intersection of several fields.

When asked about the usefulness of the tool, participants highlighted a number of benefits, including getting 'a better overview over the publications' (R9, e-mail) thanks to 'such an impressive database' (R7, e-mail). The tool was deemed useful at different levels: it allows researchers to 'keep track on the latest publications' (R9, e-mail), affords 'a nice meta-analysis and discussion about the HCI and food literature' (R6, e-mail), and makes it possible to 'find underexplored opportunities' (R6, e-mail). Researchers were also enthusiastic about the community functionalities, noting that 'it enables you to check back with the researchers' (R7, e-mail).

When asked about improvements to the app, participants suggested minor changes: adding detailed information about the taxonomy, and graphic design refinements such as highlighting the title of publications in the data visualisation. They also proposed new functionalities. Some wanted to be able to 'zoom into the visualisation so that the individual publication points are easier to click on' (R9, e-mail). A number of researchers asked us to display the number of papers associated with specific clusters of data (DIS'18, conversation). Some suggested combining manual data analysis with automated data collection, now that we have a comprehensive list of HFI-dissemination venues.

Dataset. Participants found our dataset comprehensive. At DIS'18, it was common that they checked the raw dataset to find whether it included their papers or papers they knew about. Only one participant noted (two) missing papers. In the e-mail responses, 8 authors suggested a total of 9 new papers. They have since been added. Researchers also helped identify repetitions we had missed, now corrected.

Data analysis. There were researchers who agreed with our analyses, and others who challenged them. Most of the suggested changes were minor, except one, which required a significantly different position on the agency and focus continuums, and a different domain. All suggested changes were implemented by the study participants using the online tool.

Conceptual model. The taxonomy underlying the data visualisation tool seemed to resonate with all participants' understandings of HFI, those at DIS'18 and those who responded to the e-mail request. According to researchers at DIS'18, the lenses respond to relevant issues. Some noted that these same lenses could be useful beyond HFI, to discuss the interplay between humans and technology more broadly.

Overall, participants said they found the taxonomy appropriate, though some noted issues that could be addressed moving forward. Some suggested allowing the choice of multiple domains, as many publications refer to more than one

area of food-practice (e.g. producing and eating). Some suggested that the eating domain was not 'on the same level as the others' (R1, e-mail). They 'could see many different styles of papers getting that filter' (R6, e-mail). R1 proposed 'consume' as an alternative name for this category. Some participants suggested rethinking the Focus lens, using a different encoding to allow representation of papers that refer to 'all sorts of dimensions simultaneously' (R7, e-mail). R3 suggested adding a new domain 'or some other indicator referring to 'methods" to 'question what we do in HFI' and 'challenge the status quo of food-tech design much more than we're doing right now though our HFI works'. Finally, R7 wondered whether it was possible to open 'space for [...] post-human approaches.'

Changes to the Online Tool

Inspired by this feedback, we implemented a number of changes to the HFI Lit Review App. On an interface level, we fixed typos and minor bugs spotted by participants and added detailed information about the taxonomy. For the conceptual model, we allowed for multiple domains, adjusting both the database and the visualisation accordingly. We also created a list of future changes to implement, moving forward. We describe those changes, as well as how we intend to address them, in the *Future work* section.

6 CHARACTERISING HFI

After the community validation process, we ran a final round of data analysis using the latest version of the tool and the updated dataset (270 publications). Our aims were twofold: i) to illustrate how the tool can be used and ii) to validate if the trends identified initially still held, following the recent changes. Our analysis offers general insights—an overview rather than an in-depth review.

We first tested the robustness of trends found in our initial analysis. We confirmed the radical growth of HFI: 6% of papers in the dataset were published before 2009; 51% in the following six years (2010-15); 43% in the last two and a half years, (2016-mid 2018). When looking at the Agency lens (Figure 5), human-centric papers seemed to dominate somewhat, though it was not clear if this was actually the case. A quantitative analysis revealed that contributions that attribute agency to technology (52%) are slightly more common

Figure 5: Screenshots of the data visualization, displaying individual readings of the categories in the lens of agency.

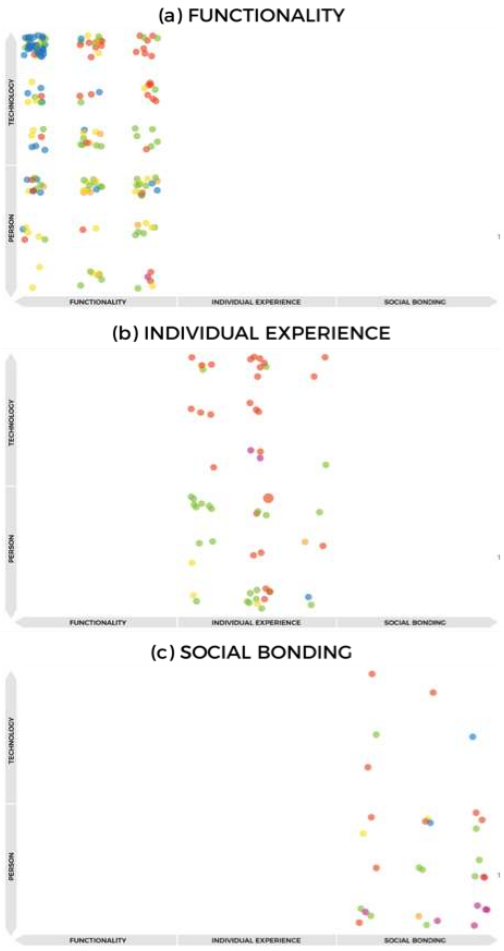

Figure 6: Screenshots of the data visualization, displaying individual readings of the categories in the lens of focus.

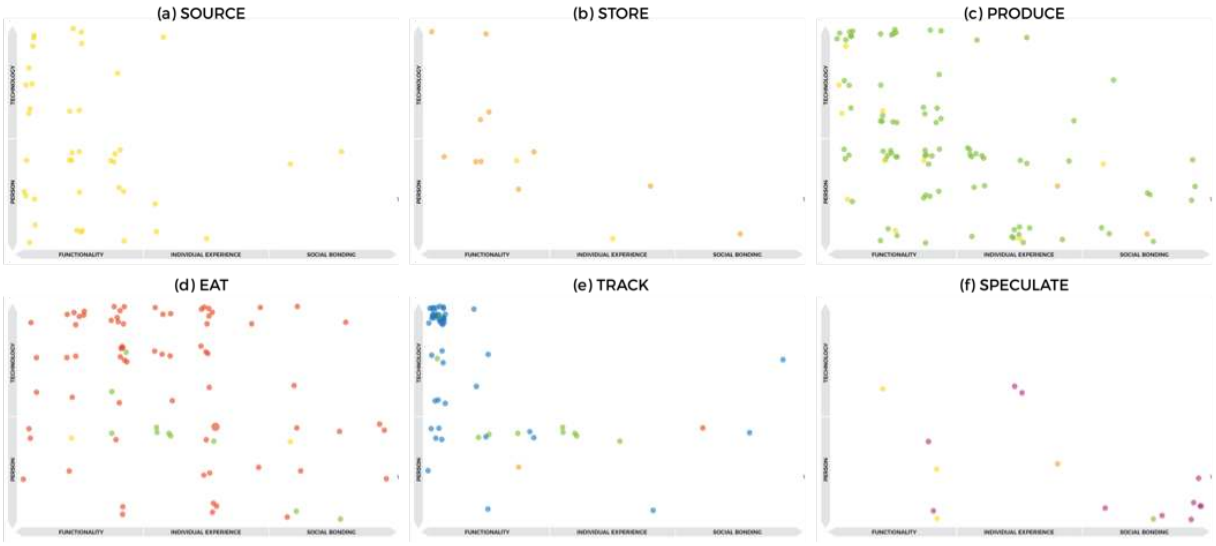

Figure 7: Screenshots of the data visualization, displaying individual readings of the different categories in the lens of domain.

than those that use technology to support people in their agency (48%). A high concentration of technology-centric contributions in the *track* domain, resulting in a dense cluster of blue dots in a small area (Figure 5a, top-left) seems to prompt this misreading. This discrepancy confirms what many HFI researchers noted: there is value in combining the qualitative input offered by the visualisation with quantitative data. When examining the data through the Focus lens (Figure 6), we noted that functionality-oriented papers (66%) outweigh experience-related ones (34%). Similarly, research on individual experience of food (22%) is more common than that on social aspects of food practice (12%).

Despite having modified the app to allow data points with more than one domain—enabling the analysis of contributions that are concerned with multiple areas of food practice at once—we could still confirm that there is an unequal distribution of concerns within HFI (see Figure 6). We found that production of food is the most researched space (37%), followed closely by eating (30%) and tracking (23%). To a lesser extent, contributions related to sourcing (15%) are also present in the dataset. Those categorized as speculate (6%) and store (5%) are in the minority.

Domain-Specific Trends

After verifying the trends from our early analysis, we conducted a more in-depth dive into the data. We examined the six human-food interaction domains to identify trends and opportunities for research. We report our findings here.

Source. Most papers exploring food sourcing embrace an instrumental idea of technology (Figure 7a), focusing on an artefact's functionalities rather than on the experience of interacting with it. In terms of agency, we see a balance between contributions that leverage technology automation (e.g. a meal recommendation algorithm [66]) and those that empower users to source food themselves (e.g. a system to support urban foraging [23]). Some *source* papers are co-categorised in the *produce* domain.

Store. Similar to the *source* domain, publications categorised in the *store* domain tend to be functionality-oriented (Figure 7b). Most data points are situated in the middle of the agency continuum, and combine technology automation with user empowerment. For example, a study of food waste reduction systems that leverage color-coding and camera tracking to encourage and support behaviour change [27].

Produce is the dominant domain in the dataset. It presents a higher diversity of foci than other domains (Figure 7c). However, functionality-oriented research still outweighs experience-related research. Significantly, we see a correlation between a produce publication's approach to agency and its position on the focus continuum. Research concerned with experiential and social aspects of food production tend to embrace a more human-centric stance to HFI than a functionality oriented stance. Some produce papers are co-categorised in the *source* and/or eat *domains*.

Eat may be the most balanced domain in terms of focus (Figure 7d). However, papers with a social approach are still less common than those concerned with individual eating experience. This outcome is explained by the fact that many works in the *eat* domain belong to the Multisensory HFI community, whose focus is to unpack the impact of multisensory stimuli on the perception of taste at an individual level. In terms of agency, technology-centric contributions

dominate (e.g. a pervasive game to modify eating habits [37]). However, there are also a number of papers that embrace a more human-centric stance to eating-related HFI (e.g. a study on the opportunities for playful social interactions in fine dining [6]). A number of papers in the *eat* domain are co-categorised as *source*, *produce* and/or *track*.

Track. As indicated by the cluster of blue dots on Figure 7e, *track* is the domain that leans more towards functionality-oriented, technology-centric approaches to HFI. *Track* papers often embrace an instrumental idea of technology, focusing on functionality rather than experiential or social factors, e.g. a multi-device food logging system that supports nutritional tracking [57]. While there are exceptions to this rule (e.g. a study of online social dynamics related to healthy eating [14]), they remain limited. Publications in the *track* domain are sometimes co-categorised as *store* and/or *produce*.

Speculate. Although speculative approaches to HFI seem to be gaining traction, they are still in the minority. Most research in this domain has been published since 2015. *Speculate* shows a different landscape than other domains (see Figure 7f). Contrary to technology-centric trends, most speculative research investigates how humans might gain more agency in their relationship with food. Many publications in this domain focus on social phenomena surrounding food practice. For example, [24] encourages citizens to co-design DIY low-cost technology to support "smart" food practices. Papers in the *speculate* domain are often co-categorised as *source*, *store* or *produce*.

7 DISCUSSION

A Living Set of Tools for Community Sense-Making

The key contribution of our Systematic Mapping Study are the HFI Lit Review App and the underlying conceptual model. Our goal is not to achieve a detailed characterisation of HFI, but rather provide conceptual and operational tools so that HFI researchers can engage with the literature and come to conclusions that reflect their own concerns. Rather than a literature review presented in linear form, we offer a set of tools that afford diffractive reading of HFI research. Diffractive reading not only acknowledges difference, but values its effects—it supports divergent perspectives and thereby accommodates the inherent heterogeneity of HFI. Rather than perform sense-making, our tools support its emergence by enabling diverse community actors to: (1) make their own sense of what they discover, and (2) collectively contribute to higher level reflections on the field.

Our contribution is a foundation from which to make sense, rather than a static review that weaves a particular view of the current state of the art. We argue that such a move is critically useful for HFI—a field that, to date, lacks common standards. Our Lit Review app and taxonomy are open-ended and inclusive mechanisms for researchers to negotiate their own understandings of HFI. Together, they afford more democratic—and useful—sense-making than could be achieved if we were to claim authority of our perspective on this remarkably heterogeneous field. Our community validation process supports this stance: researchers from divergent backgrounds confirm the usefulness of the tool; they used the model to make different sense of the HFI literature and raise useful insights that assisted us to evolve the model. While responses to our survey were minimal (11 from 129 authors), those who responded expressed enthusiasm for the tool, saying that it responded to an important need. A key factor of its success will be if researchers appropriate it, and share leadership and input through representation on the 'quality control' committee. Moving forward, we expect to organise inclusive events to discuss and rethink the app and conceptual model, and—as a community—identify and address upcoming challenges and opportunities emerging in HFI. Our contribution can be considered a living, breathing set of tools that can—and should—grow with the field. In doing so it will make visible evolving understandings of HFI.

Challenges Emerging in HFI

Using our tool and conceptual model, we examined the current state of HFI research, mapping remarkably divergent research concerns through a single conceptual model. In our analysis, we identified a number of challenges the HFI community can respond to, e.g. a dominance of *techno-solutionist* [45] approaches to HFI. In our dataset, contributions that fix, speed up, ease, or otherwise make interactions with food more efficient, clearly outweigh those that explore the social, playful, or cultural aspects of food practices. We identified few interventions that support social bonding around food, e.g. technology-mediated eating experiences that put the focus beyond the individual (e.g. [24, 29]). Yet, such aspects are important to human relationships with (and through) food [65]. Instrumental approaches to HFI produce invaluable knowledge on how to optimize our interactions with food. However, we believe they could be balanced with other approaches that examine the human-food-technology triad from different lenses.

We also saw a dominance of technology-centric approaches in *source*, *produce* and *track* papers. We suggest that enhancing user agency—using technology to support people to conduct food practices by themselves, rather than simply doing the task for them—has value. Approaches such as [14, 24, 61], for example, decrease the centrality of technology in the interplay between humans and food, and lead to enriched experiences. Critical reflection on the notions of agency and focus may be key to shaping the future of HFI. Such focus could help to ensure that advances in technology do not

come at the cost of enriched, embodied engagement with and through food.

Strength in Diversity

HFI encompasses a diversity of approaches, methodologies and aims. While diversity is certainly an asset, it can also be a barrier to communication and knowledge sharing between researchers. Our dataset indicates little crossover between the three communities we identified within HFI research. We suggest this lack of crossover may impact research. The rapid growth of HFI as a research area can make it difficult for researchers to keep track of changes in the field, let alone make sense of these changes—individually or as a community. While conference workshops allow scholars to gather, conferences happen once a year. There is some transversal movement between conferences. Nonetheless, there seems little to no crossover between the three HFI communities, in part because researchers come from different backgrounds, embrace different methodologies, and pursue different outcomes. We believe these differences can be a barrier to establishing fruitful conversations about the future of the field as a whole. Our tool aims to address such barriers by being openly accessible—online—and by encompassing the rich plurality of perspectives within HFI. It is a lightweight mechanism to support community sense-making of the field that affords negotiation in the analysis of HFI works, and can therefore facilitate and strengthen community bonds. It also enables researchers to contrast often divergent perspectives without having to meet. It thus facilitates on-going mapping of the evolution of HFI, between conferences and communities.

Responses to our tool suggest it could be useful beyond HFI, to characterise fields of research that are similarly dynamic, heterogeneous and emergent. Our taxonomy and tool afford analysis of divergent publications through a diversity of perspectives. They facilitate community-driven sense-making of a research field. The app enables diffractive reading of the data, and allows scholars from different disciplines to take divergent perspectives on the same dataset—to identify gaps, critically engage with and position their research concerns within the field. Further, because the tool is open and online, it is available to any interested researcher. We believe our approach might help emerging researchers in particular to track, shape and rethink the evolution of other research fields that are as fluid and diverse as HFI.

Our study demonstrates the potential of combining human and computational skills. Computation affords visualization of overwhelming datasets—it provided us with an overview of HFI, and allowed us to filter the data to specific queries. While we leveraged computation where possible, human skill was key to our study. Collecting publications manually allowed us to experience the nuances of the data first hand, because we had no choice but to engage with it deeply to make sense of it. The resulting knowledge facilitated the creation of our conceptual model—a taxonomy of the HFI field that responds to a diversity of perspectives. Embracing a qualitative and interpretive approach to data analysis ensured an appropriately rich construction of the dataset. Further, by involving the community in the interpretation and classification of their research, we could ensure that the dataset reflected differing understandings of HFI. We suggest that combining computational and human efforts might be useful in other fields. Although it requires effort, it affords rich, nuanced analysis of contributions. We argue that such characteristics are important, in particular when characterising emerging fields.

8 FUTURE WORK

For the HFI Lit Review App to be useful, the dataset must be updated whenever there is a conference, event or journal issue that includes HFI-related publications. Further, to ensure robust quality control that accurately represents the community, the committee undertaking this task must have a rotating membership that includes researchers from the three communities identified.

During our study, a number of interface changes were proposed for our tool. For example, displaying the number of data points in an area selected by the user or enabling zoom to explore clusters in detail. We intend to address these changes. We also plan to implement an algorithm to scrape publications automatically from known sources and to extend the tool to indicate new data points. Doing so will enable us to sustainably complement human and computational methods, and thereby ensure that the HFI database is robust and reflective of the diverse community's concerns.

Participants also offered insights into the taxonomy. Some changes have been implemented (e.g. allowing multiple domains). Moving forward, we will consider expanding the taxonomy by: rethinking the focus lens, for example to better respond to contributions that are both functional and socially-oriented; highlighting post-human approaches; or implementing new domains, for example to enable categorisation of methodology-related contributions. To ensure relevance, we will open up this process to other researchers through community consultation.

Finally, we will develop our approach to mapping emerging fields of research by expanding our focus beyond HFI. We have identified a number of researchers from diverse multidisciplinary fields (e.g. Animal-Computer Interaction, and internet of worn things) who are interested to work with us, to adapt the model to fit their fields of interest. We anticipate this expansion beyond HFI will lead to an enrichment of the process we describe here.

9 CONCLUSION

We have presented a Systematic Mapping Study of Human-Food Interaction research. To facilitate the mapping study, we created a dataset of 270 HFI-related publications and developed a taxonomy to categorise them. We developed an online data visualisation tool to afford diffractive reading of the data, and analysis from divergent perspectives. Using the tool, we identified trends in the HFI research landscape. For example, we saw a remarkable diversity of approaches, and a dominance of instrumental approaches to the role of technology in food practice. These trends allow us to highlight challenges and opportunities that HFI researchers may need to address. We also identified a need for mechanisms—such as our tool and taxonomy—that afford ongoing community sense-making. Further, we identified the notions of agency and focus as being particularly useful to reflect on both the state and potential of HFI research.

The trends, challenges and opportunities we present here represent the current state of HFI—a state that, because of the fluid nature of the field, we expect will evolve rapidly. We encourage the community to revisit our analysis regularly, using our tool, to co-create a continually evolving dataset and reflect on the interrelation of publications through varied interpretive lenses. Our tool is lightweight and accessible, and affords rich interaction between researchers. Its ongoing usefulness depends on community interaction.

Our HFI Lit Review App leverages the potential of computational tools to visualize a complex dataset and embraces community-driven qualitative interpretation of data. The tool is designed to afford diffractive reading of the dataset, allowing the reader to embrace divergent perspectives. Our approach brings together quantitative and qualitative, computational and human methods. We believe it can add value beyond HFI, and that further research will help unpack that value. We discussed how this approach may be useful in fields that share HFI's dynamic and heterogeneous nature. Interaction with other researchers confirmed our impression that our approach has relevance beyond HFI. To test this potential, we intend to continue developing the tool, both within and beyond HFI.

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