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Beyond just generative AI for discovering software opportunities

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Abstract

INSIGHTS is a digital tool for inventing creative requirements from large volumes of project-related information. It goes beyond generative AI chatbots by combining technologies that operationalise different characteristics of an integrated model of creative processes and outcomes. Its potential was demonstrated during two workshops to explore next-generation product features for a line of domestic appliances and alternative uses of bi-products from power generation. The paper ends by outlining further capabilities and discussing the tool's role in discovering creative opportunities for software product features.

Keywords/Index items

Requirements engineering, artificial intelligence, creative thinking, models of creativity, software support

Introduction

Requirements practices for software-based systems have evolved from eliciting and acquiring requirements to surfacing [1] and inventing them [2]. Many creative thinking techniques (e.g., [3]) and digital tools (e.g., [4]) already exist to invent requirements, but generative AI technologies have the potential to transform this invention process. One question is how? This paper explores how generative AI can be integrated with other forms of machine reasoning using a model that codifies characteristics of creative thinking processes and outcomes to invent opportunities from large volumes of project-related information. It motivates and describes the model, its implementation in one tool, and two evaluations of this tool's impact in different sectors.

GPTs and their limitations

Generative Pre-trained Transformer (GPT) neural networks seek to predict accurate sequences of words for input text prompts using Large Language Models (LLMs) trained on massive language datasets. Implementations such as GPT-4o can create requirements by manipulating large volumes of information from beyond organisational boundaries, and chatbots allow stakeholders to interact naturally with these implementations to explore requirements. Chatbot uses in business contexts have been shown to support consultants to generate more ideas [5] and deliver higher quality results [6]. However, questions remain about GPT capabilities to explore radically new spaces of ideas (e.g., [7]). Furthermore, GPTs

do not reason directly with heuristics or others forms of codified knowledge about established creative thinking processes and outcomes to explore these radical new spaces effectively. Indeed, over-reliance on GPTs without this accepted creative thinking know-how might be a retrograde step.

A model of discovering product opportunities

Unlike GPTs, INSIGHTS operates using a model that describes how to discover novel product opportunities and what forms these opportunities might take. This model was developed to inform INSIGHTS' design and integrates four functions of creativity models from the structuralist tradition [8]. This tradition describes how problem and solution information can be manipulated to explore and combine opportunities and, most importantly, transform spaces in which to discover these opportunities [9]. The four functions describe different but overlapping characteristics of creative opportunities and the spaces in which these opportunities can be discovered:

1. More creative opportunities emerge from systematic explorations of opportunity spaces composed of large numbers of partial and complete opportunities. Boden [9] describes how problem and solution information can be manipulated using generative rules to discover opportunities that are creative from the large numbers of possible opportunities. This manipulation of problem and solution information is consistent with existing treatments of available requirements information (e.g., [10]), but to produce creative outcomes.
2. In product development, each different opportunity space can describe all of the possible opportunities that meet the needs for one recognised class of product [Maher & Fisher 2011]. Therefore, discovering and defining these spaces using available information about existing product needs and features can be an effective baseline for discovering creative opportunities in and between spaces. It contributes to the value of the creative outcomes.
3. More novel opportunities in each product space have higher semantic distances from the centroid of that space [11]. Novelty is an essential attribute of any creative outcome [12], and more novel product opportunities have greater semantic distances from the most common examples of these opportunities [11]. Applying generative rules to discover opportunities in one space that have greater differences with common examples has the potential to direct creative thinking about product features, leading to quicker innovation.
4. More novel opportunities have predefined creative qualities. Whereas the first three functions define the creative potential of opportunities relative to other ones, the fourth identifies attribute qualities of individual opportunities associated with creative outcomes. Previous research revealed that digital products have recurring qualities (e.g., more *informative* or *playful*) that render them more creative in the eyes of users [2], similar to earlier taxonomies of recurring qualities of creative engineering solutions [13]. Therefore, generative rules can also be applied to discover opportunities with these qualities, again leading to quicker innovation.

Consider the example of a domestic appliances manufacturer exploring ideas to improve its customer service using new product features. The model identifies different spaces of

opportunities using the manufacturer's information about product needs and features. Figure 1 visually depicts three of these spaces bounded by dotted lines. Large numbers of opportunities depicted as black dots exist in each space, each with different semantic distances d to its centroid – the white dots. Opportunities can also exist between opportunity spaces. This explicit representation of and control over different spaces of opportunities is a key distinction from black-box local LLMs constructed with GPTs from the same information, and offers users greater control over the procedure, consistent with human-centred AI principles [14].

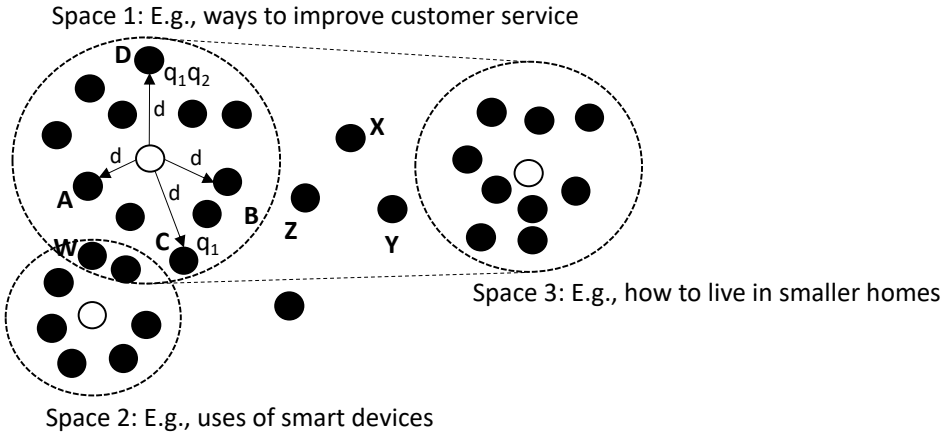


Figure 1: A visual representation of three spaces of possible opportunities for a manufacturer of domestic appliances to consider 1: Ways to improve customer services; 2: Uses of smart devices, and 3: How to live in smaller homes. Each space's centroid describes the most average and hence the least novel opportunity in that space, and all other opportunities in each space have a semantic distance from this average opportunity. The greater the semantic distance, the greater the novelty and hence creative potential, with possible opportunities between spaces having even greater potential. Each opportunity can also have one or more qualities associated with more creative potential. The greater number of qualities the opportunity has, the greater its potential creativity.

Four of the opportunities in Space 1 are labelled A, B, C and D. Opportunity A has a shorter distance to the centroid of the space than do B, C and D, so A is the least novel, and hence has the least creative potential of the four opportunities to improve customer service. One such opportunity might be a *24/7 helpline to improve customer service*. Opportunities B, C and D all have larger but similar semantic distances from the centroid, so according to the model all have higher novelty than A. While B (e.g., *a website providing different service choices to customers*) and C (e.g., *dedicated service agents for customers*) each have one predefined creative quality (q_1 (greater information and choice) and q_2 (more trust)) [Giunta et al. 2022], D (e.g., *up-to-date information with which customers can contact their dedicated service agent*) has both, so D has the potential to be more novel and hence creative than B or C.

Opportunities can also be discovered in spaces that intersect two or more spaces. These combinational opportunities are potentially more useful than others as they address multiple product needs, and are also more creative because of their greater semantic distances from the centroids of each space. E.g., the opportunity W in Figure 1 exists at the intersection of spaces 1 and 2 might propose *dedicated service agents via smart device apps*.

However, according to the model, opportunities with even greater creative potential can be discovered between the existing spaces of opportunities, i.e., in spaces not identified by current known problems and needs. These opportunities are often the outcomes of transformational creative thinking in new spaces that emerge by changing boundaries on spaces to generate new ones [9]. E.g., the opportunity X in Figure 1 is depicted to be equidistance between the boundaries of Space 1 and Space 3. One example of X might be *a service advising on efficient living with the manufacturer's products*. Opportunities Y and Z also exist in this new space but are semantically closer to the original spaces and would share more content with other opportunities in each.

To conclude, the model describes four elements of creative opportunities of software and other types of products. However, to direct stakeholders to discover these opportunities from large volumes of information, the model and its generative rules need to be implemented using an automated procedure. This procedure and the interactive features that stakeholders can use to control it were implemented in the INSIGHTS tool.

The INSIGHTS tool

INSIGHTS is a digital tool that generates multiple spaces of large numbers of opportunities with different degrees of creative potential from large volumes of unstructured information. This information can describe e.g., requirements problems, product markets, and known solution technologies, and can be found in document types from specifications and usability reports to pitch decks. It can be stored as PDF, MS Word and PowerPoint file types, include tables or graphics, and be expressed in different languages. Information defining one space of opportunities can be spread across files, repeating with different degrees of variance, and interleaved with information defining other spaces. INSIGHTS ingestion of such diverse inputs in their original forms reflects our intentions for it to be a practical tool for organisations.

After INSIGHTS has processed a set of input files, users can select opportunity spaces generated from the file's content, define how novel opportunities in or between these spaces should be, and the creative qualities these opportunities should have. INSIGHTS then applies different generative rules to discover creative opportunities within and/or between these spaces. Let us explore this implementation in further detail.

Discover and label spaces of opportunities

The procedure first extracts text from each file type (e.g., from PDF, HTML and even image files using optical character recognition) with python libraries such as *pdftotext* and *pypdf*, exploring nested pockets of content elements to retrieve all text. Other text extraction libraries are listed in Example A in Figure 2. After manually setting parameter values to reflect the file sizes, numbers and content types, a cleaning algorithm automatically manipulates all of the text to remove extra spaces, standardise characters and expunge anomalies. If text was written in languages other than English, it is translated using the *DeepL* service. This fully automated step was implemented to process the files systematically and quickly.

The procedure then applies topic modelling to generate opportunity spaces. Topic modelling is a form of statistical modelling that uses unsupervised machine learning to discover clusters of similar words within the extracted text corpus. The *BERTopic* software was chosen because of its reliability and scalability with incomplete and unstructured information. It implements UMAP to reduce the dimensionality of text embeddings, HDBSCAN to cluster the reduced embeddings, then class-based TF-IDF to extract and reduce topics, and Maximal Marginal Relevance to improve the coherence of words. As a consequence, semantic structures in the text are used to cluster unstructured data without predefined tags, training data or user intervention. Each generated cluster defines one opportunity space as a multi-dimensional space of information pieces expressed as weighted topic terms, in which more similar pieces are closer together. No LLM training is involved.

To offer users greater choice, INSIGHTS uses rules to generate three sets of opportunity spaces of different sizes for each set of input files. These rules generate between four and eight broad opportunity spaces, eight and 15 typical opportunity spaces, and 15 and 30 narrow opportunity spaces, based on prior user feedback. Weighted terms define the subject matter of opportunities in each space. A 100-word human-readable label is then generated for each discovered space by inputting the space topic terms and weightings into a generative implemented as the GPT prompt in Figure 2's Example B. The word length was also set during earlier user testing to balance between readability and detail.

Example A
Implemented BERTopic libraries for text extraction

```
for PDF: 'pdftotext' and 'pypdf'
for OCR recognition: 'pytesseract' and 'pdf2image'
for MS Word: 'docx2python'
for MS Powerpoint: 'python-ppt'
for HTML: 'html2text'
```

Example B
The generative rule to create an opportunity space description for technical design project, implemented as GPT prompt version GPT-4o, August 2024. The prompt takes as its input a list of weighted keywords that describe the opportunity space generated during topic modelling. GPT settings were temperature=0.7, top_p=1, frequence penalty=0, presence penalty=0.

You are an experienced consultant. Generate a single paragraph of 100-words that accurately describes the design area characterised by the following terms. Also generate a short name for the summary that does not contain a verb. Do not generate other content. The summary should use direct language that can be understood by someone with limited design knowledge. The first sentence should start with the expression "This design area is". The terms are: {**ListOfKeywords**}.

This version of the rule was implemented during both reported evaluations.

Example C
Segment of version of a generative rule to create opportunities of all types for single opportunity space, implemented as GPT prompt version GPT-4, May 2024. The prompt takes as its inputs the opportunity space description created using the rule described in Example B, an ordered list of words describing the space from the topic modelling, and a user input value indicating how novel the created opportunities should be. GPT settings were temperature=0.7, top_p=1, frequence penalty=0, presence penalty=0.

As a consultant, recommend 10 specific alternative business activities with considerable business potential for a business area and its topics. The business area is as follows. {**Opportunity space description text**}. The topics in the area are {**Opportunity space words list**}. Each activity should be based on at least one

of the topics. Each activity should be {**very prototypical | quite prototypical | typical | unusual | highly unusual**} of those in undertaken in the business area. Present each activity as an unpunctuated question that starts with "How could you" and directs the reader to explore the activity in more detail. Each question should be composed of at least 20 words.

This version of the rule was implemented during the first reported evaluation.

Example D

Segment of version of generative rule to create opportunities for technical design opportunities in a single opportunity space, implemented as GPT prompt version GPT-4o, October 2024. The prompt takes as its inputs the opportunity space description created using the rule described in Example B above, an ordered list of words describing the space from the topic modelling, and a user input value indicating how novel the created opportunities should be. GPT settings were temperature=0.7, top_p=1, frequence penalty=0, presence penalty=0.

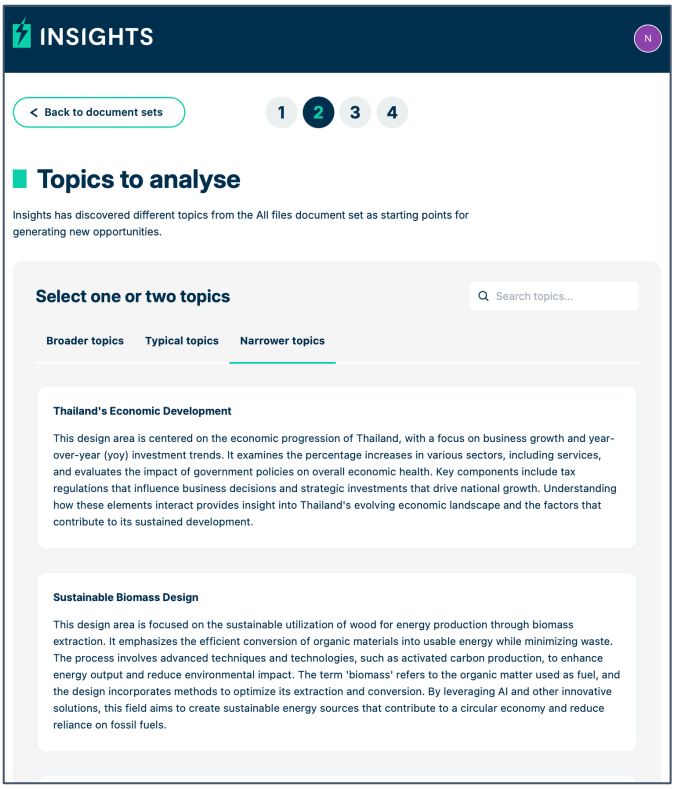
As an experienced technical design consultant, recommend 10 specific alternative technical design features with considerable novelty for a defined design area and its topics. The design area is as follows. {**Opportunity space description text**}. The topics in the area are {**Opportunity space words list**}. Each technical feature should be based on at least one of the topics. Each feature should be {**very prototypical | quite prototypical | typical | unusual | highly unusual**} of those in undertaken in the design area. Describe each feature in technical terms. At least half of the description must describe how the feature might be implemented. Each feature should be described in at least 100 words and presented as a title of up to 10 words, a colon character and the 100-word description. Don't use bullets, and new lines either in the title or the description.

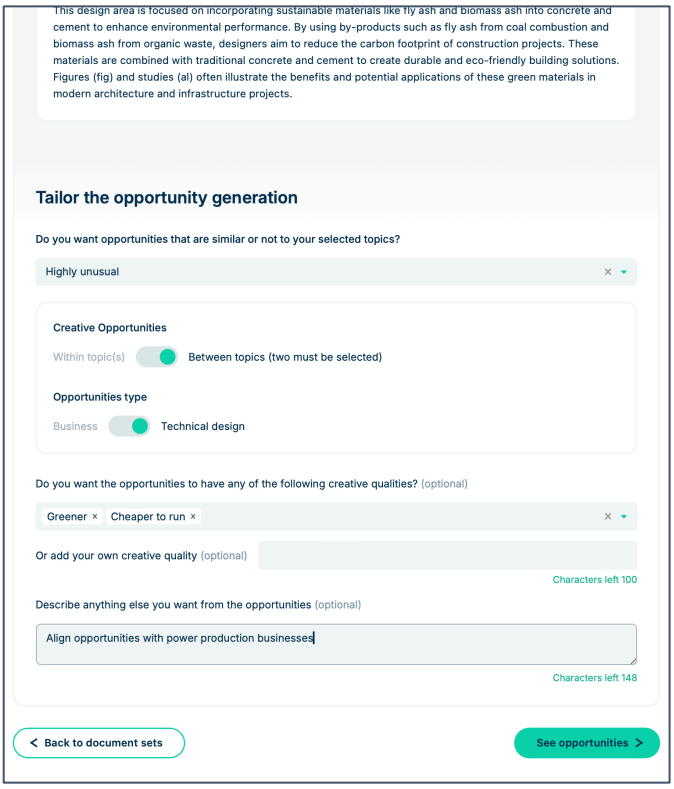
This version of the rule was implemented during the second reported evaluation.

Figure 2 – Four examples of implementation features of INSIGHTS automated procedure. Example A is a more list of the libraries used for text extraction. Examples B, C and D demonstrate segments of generative rules implemented as GPT prompts to create opportunity space descriptions, and to create opportunities during the tool evaluations reported in a later section

Discover and elaborate possibilities

The generated opportunity space descriptions are then presented to users via an interface (Figure 3) that allows them to select which space(s) to explore (Figure 3a), how novel opportunities should be, and the creative qualities (e.g., *more entertaining*, *higher productivity*) the possibilities should have (Figure 3b) drawn from a taxonomy of 22 codified qualities [2]. Stakeholders can also enter free text to describe other desired attributes of opportunities to generate (Figure 3b).


INSIGHTS
N
Back to document sets
1
2
3
4
Topics to analyse
Insights has discovered different topics from the All files document set as starting points for generating new opportunities.
Select one or two topics
Search topics...
Broader topics
Typical topics
Narrower topics
Thailand's Economic Development
This design area is centered on the economic progression of Thailand, with a focus on business growth and year-over-year (yoy) investment trends. It examines the percentage increases in various sectors, including services, and evaluates the impact of government policies on overall economic health. Key components include tax regulations that influence business decisions and strategic investments that drive national growth. Understanding how these elements interact provides insight into Thailand's evolving economic landscape and the factors that contribute to its sustained development.
Sustainable Biomass Design
This design area is focused on the sustainable utilization of wood for energy production through biomass extraction. It emphasizes the efficient conversion of organic materials into usable energy while minimizing waste. The process involves advanced techniques and technologies, such as activated carbon production, to enhance energy output and reduce environmental impact. The term 'biomass' refers to the organic matter used as fuel, and the design incorporates methods to optimize its extraction and conversion. By leveraging AI and other innovative solutions, this field aims to create sustainable energy sources that contribute to a circular economy and reduce reliance on fossil fuels.


This design area is focused on incorporating sustainable materials like fly ash and biomass ash into concrete and cement to enhance environmental performance. By using by-products such as fly ash from coal combustion and biomass ash from organic waste, designers aim to reduce the carbon footprint of construction projects. These materials are combined with traditional concrete and cement to create durable and eco-friendly building solutions. Figures (fig) and studies (al) often illustrate the benefits and potential applications of these green materials in modern architecture and infrastructure projects.
Tailor the opportunity generation
Do you want opportunities that are similar or not to your selected topics?
Highly unusual
Creative Opportunities
Within topic(s)
Between topics (two must be selected)
Opportunities type
Business
Technical design
Do you want the opportunities to have any of the following creative qualities? (optional)
Greener
Cheaper to run
Or add your own creative quality (optional)
Characters left 100
Describe anything else you want from the opportunities (optional)
Align opportunities with power production businesses
Characters left 148
Back to document sets
See opportunities

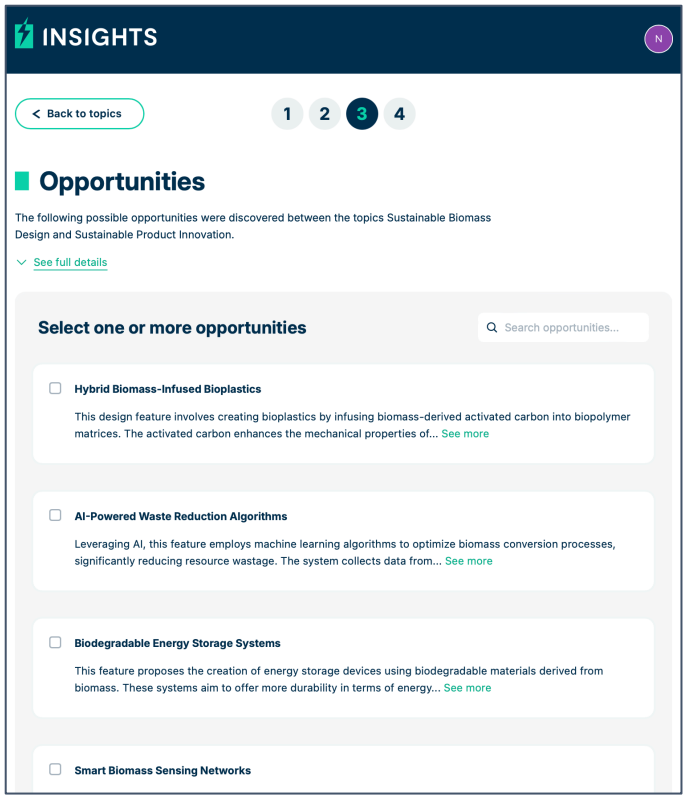


Figure 3. Examples of user interactions with the version of INSIGHTS used in the second evaluation, showing (a) examples of topics describing different discovered spaces of opportunities (called topics in the tool), (b) different stakeholder choices to direct INSIGHTS generation of creative opportunities, (c) generated opportunities for users to browse and select. The full set of 22 creative qualities that can be selected in Figure 3(b) are: increased service, added information choice, greater participation, more connected, greater trust, more convenient, greener, more entertaining, more durable, cheaper to run, more adaptable, more informative, more fashionable, inspirational, higher productivity, greater independence, more playful, more beautiful, more direct, healthier, more influential, and younger.

INSIGHTS inputs these stakeholder choices into generative rules that are applied to selected spaces. Each rule is implemented as complex parameterised GPT-4 then -4o prompts demonstrated by Examples C and D in Figure 2 to discover multiple creative opportunities to present to users, see Figure 3c. Returned opportunities are presented in list form, each described in up to 100 words established during prior user testing to balance readability and opportunity details. Stakeholders can then select multiple opportunities to export from INSIGHTS and work further with.

We assert that INSIGHTS procedure automates multiple existing requirements engineering processes and stages – document analysis, sense-making, problem scoping and early requirements discovery – while giving stakeholders control over its direction. Once stakeholders have supplied the input files, the generation of spaces and opportunities is automated, and stakeholders only need to commit time to explore the opportunity spaces and generate opportunities interactively.

The next section reports two evaluations of INSIGHTS.

Two evaluations of INSIGHTS

Two evaluations of INSIGHTS for product and process ideation were undertaken. Both explored creative opportunities to implement in large-scale software-intense products that are often the focus of requirements projects. The first, facilitated by one of the authors, took place at Miele, a manufacturer of high-end domestic appliances. Ten Miele stakeholders responsible for dishwasher innovation used INSIGHTS during a five-hour ideation workshop to explore new directions for product releases. These stakeholders ranged from experienced engineers with 30+ years of experience to marketing professionals and student interns. Prior to the workshop, INSIGHTS was loaded with 468 information documents identified by Miele: 343 dishwasher patent descriptions in English, German, Korean, Chinese and Japanese, 99 press release documents, and 26 financial reports composed of text and numerical tables. INSIGHTS generated descriptions of 9 broad spaces of opportunities e.g. *air and water purification*, 28 narrow spaces such as *plasma device manufacturing*, and 19 typical spaces, e.g., *efficient cleaning systems*.

During the workshop, the facilitator then directed the employees to explore the INSIGHTS tool using its *within-space* then *between-space* settings. Many of the opportunities generated by INSIGHTS were reported by the stakeholders to be useful if not always highly novel to them. A typical example of one such opportunity generated in the *UV air treatment solutions* space was *a self-cleaning UV lamp that uses a specific wavelength of UV light to break down organic material on the lamp surface*. However, the stakeholders reported that information coverage of the uploaded 468 files was too narrow to generate all forms of opportunities that Miele needed for next-generation product innovation, e.g. stakeholders reported also using product features from sectors such as automotive in their ideation processes. To increase this coverage, 12 new types of information, from market reports to technical specifications, were identified to add to the uploaded documents to reflect the Miele innovation process with greater accurately. This feedback revealed the need for systematic analyses of innovation information sources to generate balanced novel and useful opportunities.

Stakeholders also reported wanting greater control over the direction of the opportunities generated. E.g., the uploaded files contained mixes of technical and business/market information and INSIGHTS generated opportunities combining both. However, the Miele engineers predominantly sought technical opportunities and the marketing professionals sought business growth areas. In response, separate generative rules, i.e., pre-defined GPT prompts to generate business and technical opportunities, such as Example D in Figure 2, were implemented. Stakeholders also reported wanting to first browse space and opportunity titles without full details. These features were also implemented in a revised version of INSIGHTS that was explored during an evaluation with a second organisation.

Biomass power plants are one source of renewable energy, but the process produces biproduct biomass ash. One power company in Thailand sought alternative uses for this ash to reduce disposal costs. The revised version of INSIGHTS was populated with 100 PDF files resulting from a systematic analysis and describing research on six themes covering different problem and solution spaces: biomass ash (30), green products (16), innovative product design (12), waste initiatives (15), business trends in Thailand (12) and Thailand's biomass powerplants (15). Ten company stakeholders in management, engineering, business development and sustainability roles with up to 15 years of sector experience then

participated in one ideation workshop. During the workshop the stakeholders worked in two teams of five balanced by role and experience. The facilitator, another of this paper's authors, directed the stakeholders to generate ideas using established brainstorming techniques and common digital tools such as search engines. The facilitator then directed the stakeholders to explore the INSIGHTS tool using its *within-space* then *between-space* settings for another 45 minutes and export generated opportunities of interest into local tools such as spreadsheets. After the workshop, each stakeholder individually answered nine questions about differences between the facilitated brainstorming and use of INSIGHTS, and provided further written comments.

During the brainstorming half of the workshop the two teams generated 10 and 11 new opportunities respectively, which was reduced to a total of 17 unique opportunities when combined. Translated from Thai into English, these opportunities were between six and 12 words in length and covered four sectors – agriculture applications, construction materials, environment and filtration, and miscellaneous. Then, during the INSIGHTS half, the teams exported a further seven and eight new opportunities respectively from explorations of six opportunity spaces generated by INSIGHTS. These additional opportunities were between 50 and 99 (average 74) words in length. Equal numbers of these opportunities were generated from the *within-space* and *between-space* settings, and covered another four sectors – fashion and beauty, interior home design, packaging, and energy – in addition to the original four.

After the workshops, all ten stakeholders responded to the nine questions on 1-5 scales, see Table 1. Average responses ratings by question were all above three, indicating above-average positive views about INSIGHTS for each question. The first three questions about opportunity novelty revealed that INSIGHTS introduced new areas, e.g., "*it genuinely created various unexpected ideas*", but again the opportunities themselves were not as unique and different to industry norms as they might be. Several stakeholders reported what was perceived to be creative combinations in the opportunities, e.g., "*it can combine creative qualities to produce interesting and applicable ideas*".

	Employees										
	A	B	C	D	E	F	G	H	I	J	Av
Questions about opportunity novelty											
How unique are opportunities generated by INSIGHTS compared to traditional methods?	5	4	4	4	3	4	2	4	5	2	3.7
To what extend did INSIGHTS introduce new areas and possibilities not considered previously?	5	4	4	3	4	4	3	4	4	5	4.0
How different are these opportunities from the current trends and norms in the industry?	5	4	3	3	5	3	2	4	3	3	3.5
Questions about opportunity usefulness											
How realistic are the opportunities generated by INSIGHTS to be developed for implementation?	5	4	4	4	4	4	4	4	4	3	4.0
How easy will it be to implement the opportunities from INSIGHTS given your current resources?	5	4	4	2	5	2	2	4	4	3	3.5
Considering all factors, how would you rate the overall potential of these opportunities?	5	4	4	4	4	4	3	4	4	3	3.9
Questions about impact on wider process											
How helpful do you think INSIGHTS is in providing creative opportunities?	5	5	4	4	5	5	4	4	4	4	4.4
How well does INSIGHTS stimulate creative thinking your team?	5	5	4	4	5	4	4	4	4	4	4.3

How useful is INSIGHTS is supporting idea sharing/decision-making processes in your business?	5	4	4	5	4	4	3	4	4	4	4.1

Table 1. Employee responses to nine questions about relative INSIGHTS effectiveness in second half of the workshop, on scales of 1-5 where 5 indicated most positive responses about opportunity novelty and usefulness and impact on team, and 1 indicated most negative responses

The second three questions about opportunity usefulness revealed that INSIGHTS generated realistic opportunities with potential, e.g., "*INSIGHTS can effectively propose feasible business ideas using ash*", but ease of implementation of the opportunities scored a little lower. Some stakeholders also expressed concerns about the lack of trace to source documents that gave rise to those opportunities, e.g., "*Lacks clarity on sources of information, requiring further research, especially for unusual ideas*".

By contrast, responses to the final three questions revealed that INSIGHTS was most effective for accelerating team discussions, e.g., "*By generating new ideas and sparking team discussions, though some ideas may require further study*". It also appeared to save the teams time during this creative exploration phase, e.g., "*it takes a shorter time when finding possible solutions and help us to quickly summarise important information*" while still generating sufficiently novel and more complete opportunities.

To conclude, the stakeholders in this second workshop encountered fewer issues using INSIGHT's features, and generated useful, more diverse and more detailed opportunities more efficiently (in only 45 minutes) than with existing brainstorming approaches. However, the generated opportunities could again be more novel.

Discussions and next steps

INSIGHTS is a new tool to generate creative opportunities from existing information sources. It combines different AI technologies operationalising four elements of a model of described creative processes and outcomes as generative rules (e.g., [2, 9, 11]). Two early evaluations revealed the potential of this integrative approach to discover useful opportunities and speed up the process of discovering these opportunities. However, to generate highly novel opportunities more regularly, INSIGHTS was extended with new generative rules. One set of these rules describes information about recurring creative qualities (e.g., [2, 13) to refine how opportunities can be implemented. Another feeds generated opportunity descriptions selected by users back into the procedure to generate new opportunities, thereby enabling pivoting during creative thinking.

Based on this evidence, we assert that INSIGHTS can be advantageous for software requirements projects. It can speed up and systematise key domain analysis and requirement discovery steps both to reduce costs and increase creative potential. INSIGHTS was designed to accept, make sense of and generate opportunities from diverse unstructured content from multiple files common in requirements projects. We look forward to reporting evaluations with these projects in the near future.

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