Realization of Organic and Dynamic Creativity Support Tool for Promoting Ethical AI Design

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***Abstract*—In recent years, the significance of ethics in artificial intelligence (AI) has been increasingly recognized, and ethical principles and cases have been proposed by academic societies, administrative organizations, etc. However, it is hard to say that AI engineers have adopted these results, so there is a gap between the suggestions and the research and development.**

We therefore set the realization of organic and dynamic creativity support tool to promote ethical design by AI engineers as our objective. Here, "organic" means that the tool deals with complex relationships among different AI ethics and technologies. "Dynamic" means that the tool dynamically adopts new issues and helps engineers think in the contexts relevant to their project. We applied the ethical design theory to standardize the way of describing ethical and technical ideas in the same way. Then, we implemented a function to recommend ethical and technical scenarios according to each context of each engineer.

Through our experimental cases, we confirmed that the tool can not only connect technical ideas with ethical ones, but also promote discovery of novel design solutions because it allowed users to reconsider design ideas from highest objectives. We confirmed that the tool is useful for humanities experts, too.

***Keywords*—AI Ethics, Design Theory, Creativity Support Tool, Discovery of Novel Design Solutions**

I. Introduction

In recent years, the significance of ethics in artificial intelligence (AI) has been increasingly recognized, and ethical principles and cases have been proposed by academic societies, administrative organizations, independent foundations and others. Examples of such ethical materials include the Asilomar AI Principles [1], IEEE's reports [2], [3], and the Japanese guidelines [4]–[6]. However, there is little indication that AI engineers incorporate these results into their research and development. AI engineers are earnestly working on their own projects, and AI ethics is not currently imposed as an obligation to engineers, so the priority of AI ethics in engineering becomes low. Furthermore, when AI engineers have the interest and the time to investigate AI ethics, the relationship between their own technologies and issues of AI ethics is difficult to understand because most discourses of AI ethics are too abstract and the literature is too broad. As a result, although it is increasingly recognized that ethical AI is critical for the realization of a better society, there exists a gap between AI ethics and AI engineering.

Therefore, the research question of this paper can be as follows: is it possible to realize a creativity support tool to promote ethical design by AI engineers? We consider that the answer is positive for the following three reasons.

First, AI engineers are able to address ethical issues in their own research and development by appropriately organizing the design perspectives and methods. Here "ethics" is a system of social values, and "social values" are indicating societal-scale values such as "human dignity," "rights," "freedoms," and "cultural diversity" that have been introduced as human values in Asilomar AI Principles. We have systematized such ethical design theory to aid ethical design [7].

Second, some part of the ethical design process can be programmed because the essence of procedures in such design process is very clear as we have systematized. This is favorable to flexibly aid engineers on a large scale. So, we implemented an organic and dynamic creativity support tool. We use "organic" to mean that the tool deals with complex relationships among different AI ethics and technologies. "Dynamic" means that the tool dynamically adopts new issues and helps engineers think in the context of their own research and development.

Finally, ethics can be a creative "constraint" [8] to enable more creative designs because ethics corresponds to highest design objectives. So, if designers can logically reconsider their design from such ethical viewpoints, their design activity will be more creative both in originality and practicability as described in Subsection VI-B. Therefore, by making it easier for AI engineers to aware these positive effects of ethics, the tool will succeed in promoting ethical AI design.

II. Related Works

To support ethical AI design by engineers, we must first understand design representation in engineering. The academic discipline of design study has claimed from the beginning that a hierarchical representation is essential for design activities [9]–[11] because the relationship between objectives and means in design corresponds to the relationship between the higher and lower levels such as the system and the subsystem. Therefore, such hierarchical representations has also been used to support design activities. For example, Lee et al. said that "[I]t is necessary to classify five levels of knowledge in order to use relevant knowledge in a systematic way" [12].

The point here is that the hierarchical representations in investigating design theories and creativity support tools were mostly used to manage *function decomposition* by descending to lower levels; this representation has helped use subsystems to realize functions as a system [12]–[16]. And little research on creativity support tools has dealt with higher objectives. According to Wang et al. only seven studies dealt with such

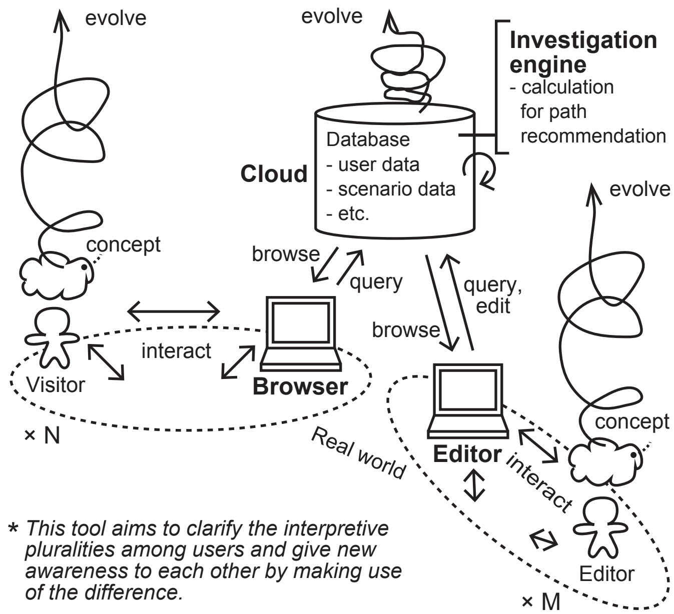

Fig. 1. Overview of the organic and dynamic tool called Dfrome

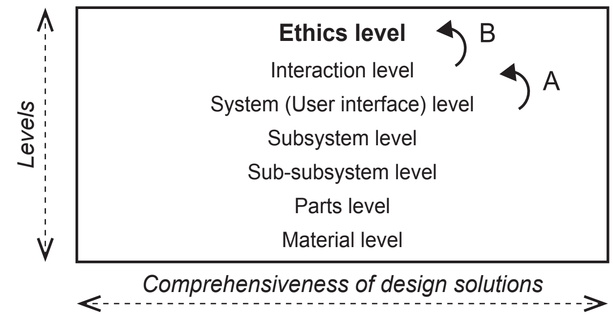

Fig. 2. Hierarchical representation of artifacts with ethics level [7]

"problem finding" approaches [17]. The reason it is rare to deal with problem finding can be considered that a proposition at the higher level is a precondition for establishing more concrete investigation at the lower levels in the hierarchical representation of artifacts.

To ensure ethics in design, however, it is essential to investigate the final objectives found in the higher levels in the hierarchy, so there is no creativity support tool available to support, e.g. ethical AI design. We therefore created an organic and dynamic creativity support tool that is to be equipped with ethical knowledge base.

III. Overview of Dfrome

In this section, we introduce and overview our organic and dynamic creativity support tool called "Dfrome," which is the abbreviation of Design FROM the Ethics level [18] that is designed to support ethical AI design by engineers. One of the most important function of Dfrome is to recommend scenario paths that address ethical issues to be considered by designers.

Dfrome consists of four components as shown in Figure 1. A browser allows visitors to confirm ethical and technical scenarios related to their own research and development. A cloud environment makes it easier to install applications and simplifies idea management and sharing. An investigation engine calculates the distance between ideas and recommends scenario paths. An interactive editor provides human editors with formats of ethical design perspectives and methods, and also lowers description workload. So, there are two types of users in the real world: N visitors for simple browsing with the browser and M human editors for editing with the editor.

Dfrome does not endorse the view that one can substitute AI for people. Instead, the aim is to demonstrate a better creativity through a combined system of people and machines. Furthermore, knowledge in Dfrome is not static, but it is instead able to evolve while AI and people interact in the locally generated context. And the tool can also enhance interactions among designers's ideas. This tool aims to clarify the interpretive pluralities among users and give new awareness to each other by making use of the difference instead of creating one and only neutral understanding. A detailed description of the processing will be given in Section V and a case will be in Section VI.

IV. Ethical Design Theory

To deal with ethics in design, we systematized a new version of the hierarchical representation of artifacts and the description method corresponding to it. The former is what we call "Design from the ethics level" and the latter "Design with discourse" [7]. And we call the set of the two parts together "Ethical design theory" which will be evaluated how practical it is, at the same time Dfrome will be evaluated in this paper.

A. Basics of Design From the Ethics Level

To begin, we referred to the hierarchical representation of artifacts based on the studies of Herbert A. Simon [9] and Hiroyuki Yoshikawa [10], [11]. For example, Simon emphasized the importance of the concept of the interface: "The artificial world is centered precisely on this interface between the inner and outer environment" (p.113 [9]). And the first interest of both researchers is in a function of such system and decomposition of it, so we can understand that their level is at the system level at most.

Subsequently, the interactions became important. Kumiyo Nakakoji stated, "While the term 'interface' makes people consider the character of an artifact as a *surface*, 'interaction' makes people consider the *time*, *flow* and the *change* that the artifact creates" (trans. by author) [19]. Therefore, the level of Nakakoji's state, namely interaction level, can be placed above the system level as shown in (A) in Figure 2.

On the extension of this perspective, we redefined the hierarchy in order to deal with ethical issues. To be a system in the hierarchy, the higher level is supposed to contain the lower level as its component. And as the influence of functions propagates more spatially widely, the value will gradually change to a more socially recognized values such as those at the ethics level. It means that the higher level needs to be wider than the lower level in space, e.g. some field is a part of a society: an interaction occurs in a field and the relevant ethics of a whole society which will be influenced corresponding to

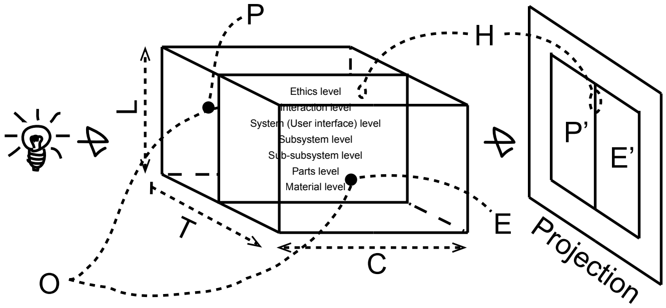

Fig. 3. Hierarchical and orthogonal representation of design ideas. L: Levels; T: Transitions of personal concerns; O: Orthogonal representation of personal concerns; H: Hierarchical representation of artifacts; P (P'): Personal reasons; E (E'): Effects on me

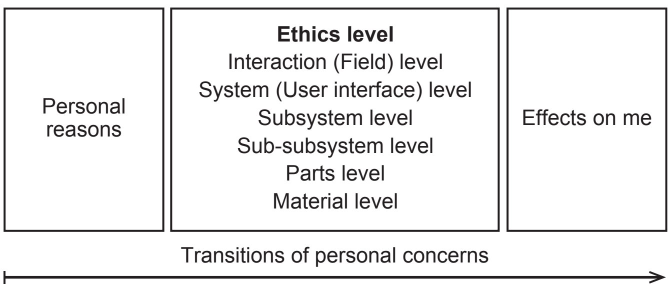

Fig. 4. Simplified version of the hierarchical and orthogonal representation of design ideas

the emergence of the field locates further outside. Therefore, the ethics level that corresponds to the whole subject is at the top of the hierarchical representation as shown in (B) in Figure 2

B. Additional Dimension of Design From the Ethics Level

We then added another dimension of ethics for personal concerns of a designer such as "beliefs," "motivations" and "incentives."[1] This is because above-mentioned hierarchical representation corresponds to the general phenomena, that is the object of the natural sciences on which engineering is based, and there is no space to describe such subjective issues. This personal dimension can be set as *orthogonal* to the hierarchy because *a designer can consider each level directly* as H and O in Figure 3, although changes must be generated from the element technologies at hand. And the order and the direction of the arrow of T in Figure 3 corresponds to the flow of time: a reason, an action, and an effect, in that order: P(P')→H→E(E') in Figure 3.

Finally, we can simplify this three-dimensional representation using the projection picture and positioning the hierarchical representation at the center as shown in Figure 4. We applied this simplified version in this research.

At the open discussion of the 31st Annual Conference of the Japanese Society for Artificial Intelligence (JSAI2017), one of the members of the ethics committee, Arisa Ema, introduced three major areas of Ethics in AI: research ethics, AI ethics, and ethical AI [20]. From our perspective, AI ethics is discussed at the ethics level; ethical AI is positioned as one of the artifacts designed in the hierarchical representation; and research ethics indicates the issues of the personal dimension that is orthogonal to the hierarchy. To the best of our knowledge, our research is the first to systematically deal with all three of these ethical dimensions as a whole.

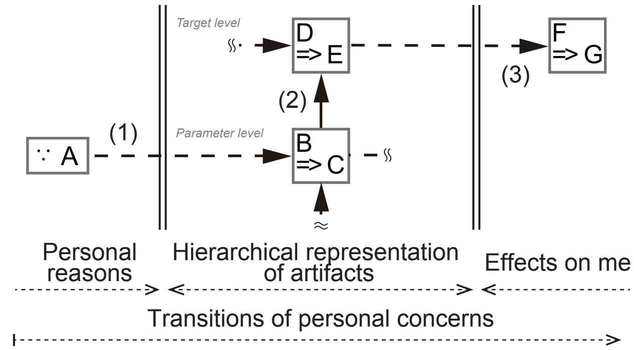

Fig. 5. Hierarchical and orthogonal grammar of design with discourse

C. Design With Discourse

We also defined a description method for expressing design ideas. This method contains a rule in which a designer is to connect changes from the level of parameters to the target level in the hierarchical representation. It also contains rules for reasons and effects in the orthogonal representation. These descriptions construct paths in describing design ideas, and the paths form a tree. An example of such descriptions is as follows and visualized image is as shown in Figure 5.

1) Since A is a personal reason, I/we generate a design that will change B to C in the hierarchical representation of artifacts.
2) If B is changed to C at the parameter level, then D will change to E at the target level in the hierarchical representation of artifacts.
3) If D is changed to E in the hierarchical representation of artifacts, then F will change to G as effects on me/us.

Support for our description rules can be found in Simon's statement that "[T]he behavior of the system at each level depended on only a very approximate, simplified, abstracted characterization of the system at the level next beneath" (p.16 [9]) and by Yoshikawa's investigation that says that, as it can be described as a differential equation, the essence of a function is to cause a change [21].

D. Example of the Ethical Design Theory

To clarify how to practice the ethical design theory and how to support it, we introduce an example of how a concrete AI design will change if we redesign an AI concerning human job deprivation.

Such job problems are related to technologies such as automated cashiers, office work robots, and auto-pilots. These

[1]The details are described in our essay. Please refer to K. Sekiguchi, The fifth rule of "design with discourse" for the orthogonal representation of moral concerns in design from the ethics level, October 30, 2010. at www.ethics-level.com

systems utilize technologies such as image recognition, natural language processing, and robust control that are required to realize each system corresponding to the necessary functions. If these technologies will be implemented as their sub-systems, the broader systems described above can or will be obtained. If and when they do, they will replace jobs currently held by people. Those people will suffer both material loses and opportunities for self-realization through their works. Such extensive automation will injure any society that strives to provide a life with freedom and equality at the ethics level. We could logically connect changes corresponding to climbing up the hierarchical design representation step by step to ethical issues such as decreasing social freedom and equality.

Using hierarchical design, we can also instead update our problem setting to design *to promote social freedom and equality* that we believe better at the ethics level. By appropriately selecting a level in the hierarchy for issues related to this point, it becomes possible to comprehensively describe them. Examples of the types of design questions we can explore in this context are as follows: Around the interaction level, what kind of roles is required for people? How do people transform when they live and work with AI? What is the difficult point for preventing terrorism against AI and AI companies? Around the system level, how can social systems such as basic income be positioned in the context of AI job deprivation? Therefore, we claim that design solutions become more comprehensive by rethinking them from a high-purpose such as ethical meanings.

In addition, there is a chance to generate novel design solutions. For example, if we take as an ethical value that AI should help to realize a more free and equal society, we can think of a design that smooths out differences of chances unreasonably imposed on people. AI can make visual information voiced to a blind person, for example. Conversely, AI can show auditory information to those who cannot hear. If such technology existed, there would be more opportunities for jobs that is difficult until now such as blind pilots and deaf musicians.

As for further detailed designs, for example, blind pilots can also be considered together with changes in requirements for pilots. Automatic driving will reduce the need for pilots' maneuverability and, therefore, the physical ability of the pilots will be less important. Meanwhile, hospitality that realizes high-quality services will become more important. Also, in emergency situations, the judgmental ability to respond flexibly and communication skills to communicate well by notifying the situation will become more important. If so, the boundary between the pilot and the cabin attendant becomes more ambiguous and, as it were, work of a flight manager is probable to be designed. In such work, blind people who are equipped with AI can more be engaged.

An visualized image of above-mentioned example was as shown in Figure 6. By redesigning the design from high objectives such as from (a) to (b), the design solution could be described more comprehensively. In addition, the utility of the ethical design theory for discovering new design solutions became clearer as the alternative path of (A) in Figure 6.

In this way, we can design a society in which people will be more appreciated by their differences such as original experiences or sensitivity which were obtained thanks to the above-mentioned differences. The point is that it is difficult for AI to have such differences and utilizing them is far more important than the idea of normalization. Our objective is to promote such design practice by engineers.

V. Scenario Path Recommendation

To dynamically realize scenario path recommendation on Dfrome, we applied the knowledge liquidization and crystallization model [22]. Dfrome first liquidized stored trees into fragmented paths, and, when a query is submitted, the tool recommends what should be considered, which depends on the local context generated with the designer. Then, the designer is to update the understanding of the design by considering the connection with respect to the recommended path. If the tree of the design is updated and published as they crystalize a new concept, then the knowledge base and corpus of the tool will be updated. In this way, our database and the designer's idea will evolve dynamically on Dfrome.

A. Calculation for Scenario Path Recommendation

Mathematically, Dfrome calculates the distance between paths. Dfrome set a vector space by applying Doc2Vec [23] due to its flexibility to synonyms and data granularity compared with bag-of-words and term frequency–inverse document frequency (tf-idf). The learning data of the vector space is a set of trees published on Dfrome and not deleted.

The paragraph vector of each description such as a change description in Figure 5 (item) will be calculated on the basis of the terms contained. Finally, with the two paragraph vectors $\boldsymbol{u}$ and $\boldsymbol{v}$, the similarity equation is given in Equation 1.

$$similarity = 1 - \frac{\boldsymbol{u} \cdot \boldsymbol{v}}{\|\boldsymbol{u}\|_2 \|\boldsymbol{v}\|_2} \quad (1)$$

For scenario path recommendation, our tool calculates similarities between paths based on the geometry in Figure 7. The horizontal axis shows the similarity between the query item of the designer's tree along with the start item of the candidate paths (querySim). The vertical axis shows similarity between the connected paths (connectedPathSim) that extend from the query or start item of paths. In Figure 7, each plot signifies a candidate path. To recommend a path, we use two metrics. One is an angle, and the other is the absolute value of similarity between the paths as shown in Figure 7. For diversifing users' thoughts, the similarity calculation is based on the angle and is shown in Equations 2 and 3.

$$totalSim = -\arctan\left(\frac{connectedPathSim}{querySim}\right) \quad (2)$$

$$\sim -\frac{1 + connectedPathSim}{1 + querySim} \quad (3)$$

We define the total similarity (totalPathSim) as negative as shown in Equation 2 to reverse the magnitude to be consistent with the other sorting in Dfrome. In Equation 3, we simplify Equation 2 and add one to the denominator and numerator to correspond to the case in which the denominator is zero.

This is the basic idea of scenario path recommendation and there are several exceptional processes, but their explanations were omitted this time because of space constraints. For

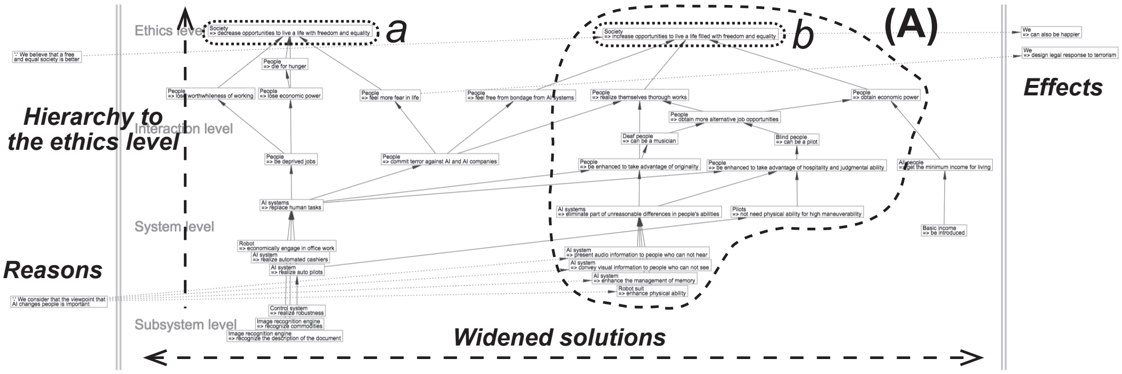

Fig. 6. Visualized image of an example of how a concrete AI design will change if we redesign an AI concerning human job deprivation whose descriptions are: (a) Society => decrease opportunities to live a life with freedom and equality; (b) Society => increase opportunities to live a life with freedom and equality

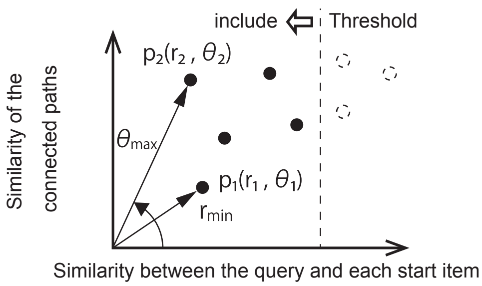

Fig. 7. Geometrical representation of path distances

TABLE I. SUMMARY OF DATA USED TO EXPERIMENTS [1]–[6], [26], [27]

Tag	Document	Details	N
EAD	Ethically Aligned Design	Principles of Version 1	4
EAD2	Ethically Aligned Design	Principles of Version 2	5
AAP	Asilomar AI Principles	Ethics and Values	14
RDP	AI R&D Guidelines	Principles	10
RDU	AI R&D Guidelines	Cases	10
DS	Drone Studies	Cases	6
ML	Machine Learning Papers	Overview of the algorithm	5
OTH	Others	Authors' design etc.	15
			69

example, if a path consists of single node as is the case in the processing of the browser, description of its connected path is set by that of its query (or start item).

B. Related Works in Detail

There is a way of three-dimensional representations [24] which uses the third dimension to describe the reasons of design changes, while we express them in a two-dimensional hierarchy such as (2) in Figure 5 and use the third dimension for the different purpose for describing personal concerns. Our way of describing is more intuitive for describing design ideas because it more clearly corresponds to the design thinking to cause changes from the parameter level to the target level.

Then, the knowledge graphs is said that "the data is in the form of a graph, consisting of nodes (entities) and labelled edges (relationships between entities)" [25], while the data in the ethical design theory is composed of changes of entities' attributions and their causality. And, for creativity support, extracting paths for diverging users' thinking became more important than extracting the ordinary facts.

VI. EVALUATIONS WITH CASES

In this section, we discuss the results of experiments using Dfrome. In order to ensure reproducibility of this experiments, data was downloaded and executed locally.

A. Summary of Data in AI Ethics Library

On Dfrome, each discourse is edited as a tree according to the ethical design theory. Summary of data is as shown in Table I. As of August, 2018, there exist 69 trees that can be used for the experimental processing. Data includes trees of ethical principles such as Asilomar AI Principles [1]–[5], six drone materials (that is an applied area of AI), five descriptions of machine learning such as [26], and authors's designs, etc.

At present, they were manually edited by the authors. For example, there is a tree of drone delivery and drone highway whose editing process was as shown in Figure 8. At first, this tree was edited individually by referring to materials such as [27], then revised while discussed with an AI ethics/AI expert and a public law expert, then revised while looking back on the discussion. For example, we discussed (1) drone certification organization, (2) relation between drone and automatic driving and (3) transparency of technology for controlling military diversion. Finally, this tree became more persuasive: it become more comprehensive (wider) and more detailed (longer). The point here is that the structure of each idea was visualized by how they were expressed in our theory.

In addition, we also discussed drone swarms as an alternative path and found that considering them are also significant from the viewpoint of legal system. We then decided to prepare for describing an academic paper. However, an explanation of its tree were omitted this time because of space constraints.

B. Evaluation of Scenario Path Recommendation

Then, we confirmed whether the tool could promote ethical AI design. For this time, we used our browser to receive scenario path recommendation. To set a query, we used Google Scholar to search papers after 2018 by querying "drone delivery" and used the abstract of the paper that appeared at the

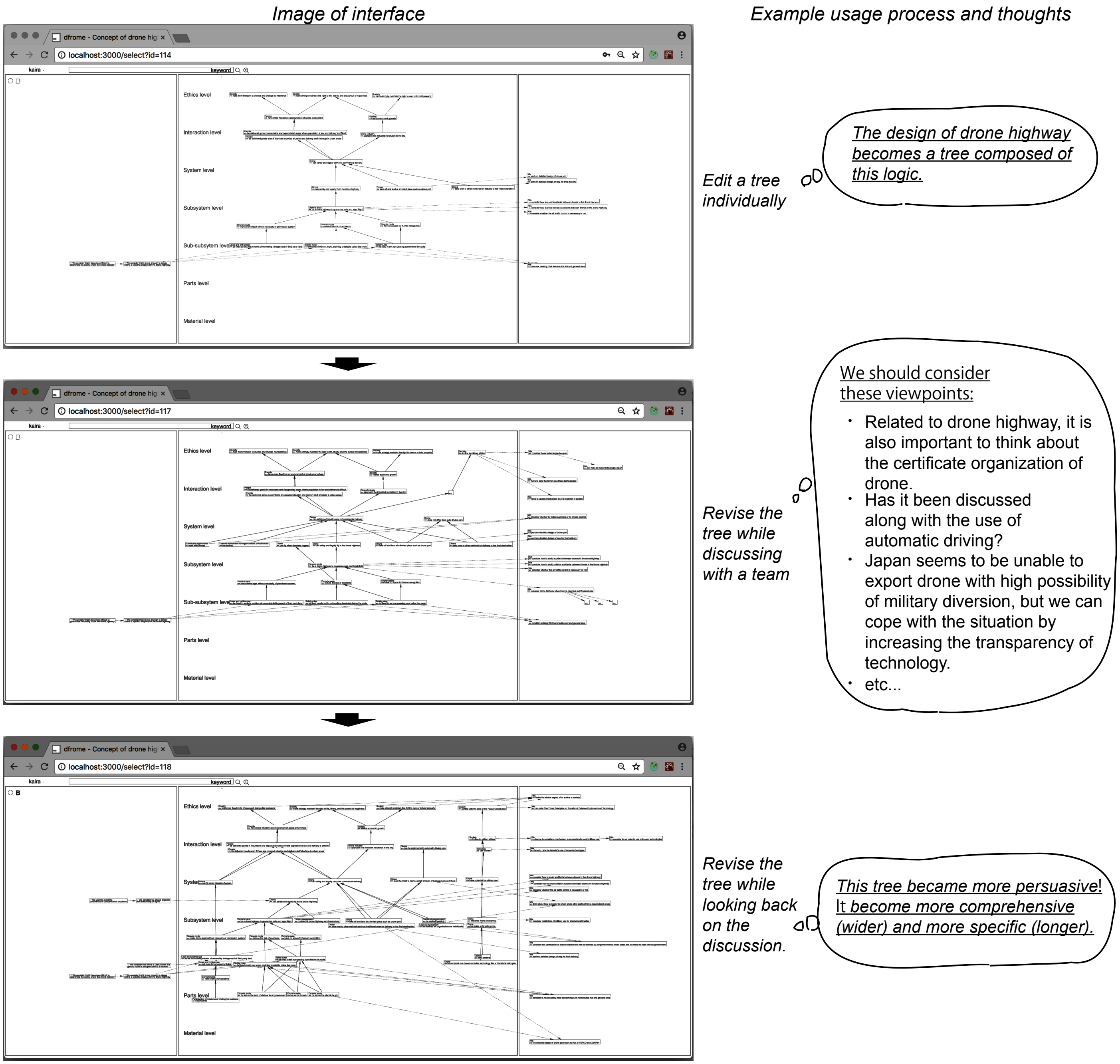

Fig. 8. Example of editing design ideas on Dfrome [27]

top of the search results (except for patents), in which drones and trucks were evaluated their CO_2 emissions, and detected general conditions "under which drones are likely to provide a CO_2 benefit." [28].

An overview of actual images of the browser and an outline of this experiment are as shown in Figure 9. At first, we received a recommendation of ethical scenarios. One of them was suggested that realizing the queried work will realize economic growth. Then, to find other technical scenarios leading to the similar effect, we set the obtained last effect, namely "Society => more strongly maintain the right to own or to hold property.," as a next query. One of the results suggested that a drone certification organization to realize drone delivery can be a trigger for the effect. So, it clearly became noticed that the researchers can update their own research by adding consideration to the certification organization, e.g. considering effects of such organization on CO_2 emissions.

The above-mentioned practice allowed us to be more original because it allowed us to reconsider the higher objectives such as "economic growth" and expand the space of design solutions such as to consider effects of a legal system such as certification organization for CO_2 emissions that was difficult to be expected at first. The point here is that the higher levels we reconsider the design from, the more the probability of find-

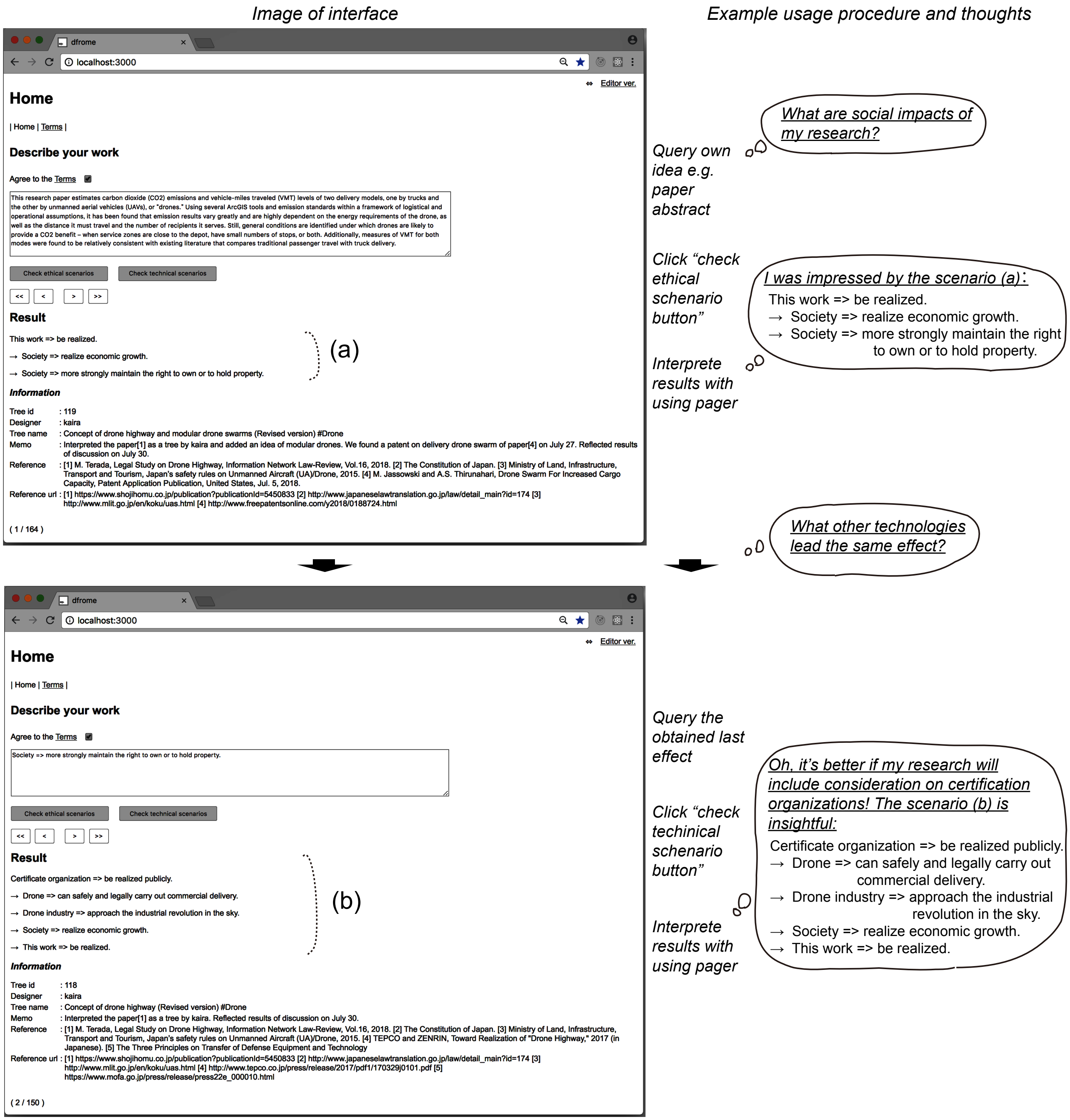

Fig. 9. Example of scenario path recommendation for finding a scenario path to the ethics level and other design solutions whose descriptions are: (a) This work => be realized; → Society => realize economic growth; → Society => more strongly maintain the rights to own or to hold property: (b) Certification organization => be realized publicly; → Drone => can safely and legally carry out commercial delivery; → Drone industry => approach the industrial revolution in the sky; → Society => realize economic growth; → be realized.

ing a novel solution becomes by confirming the consequences and spread such paths. Furthermore, it allowed us to be more practical because, due to the rules to describe the chain of changes, it became possible to logically confirm the causality.

In this way, by collecting various descriptions by teams (and, of course, by individuals), it became possible to check ethical and technical scenarios, provide awareness among their understandings and update their ideas.

VII. Conclusion and Future Works

We asked whether we could realize a creativity support tool for promoting ethical AI design by AI engineers. The application of the ethical design theory allowed us to confirm that AI engineers can connect AI ethics to their own research and development. In addition, Dfrome were able to deal with design ideas together with the designer because it can deal with ethical meanings (organic) and user's context (dynamic). Furthermore, we confirmed that considering ethics can be a creative constraint to generate new ideas, rather than a hindrance to creative activities, not only for AI engineers but also for humanities experts. This means that Dfrome were able to provide incentives to practice ethical AI design to find novel research and development themes and/or business chances. Therefore, Dfrome have succeeded in becoming such a tool.

The next step of this project is to provide Dfrome not only for AI engineers but also for other engineers and humanities experts. We plan to start such experiments from those for laboratory members in the near future. We also plan to improve functions of Dfrome such as its accountability. In addition, we will deal with the tree data as a time series to consider both the feedback of changes in trees and historical flow of contexts.

Acknowledgment

The authors wish to acknowledge Dr. Hiroshi Nakagawa and Dr. Mayu Terada for their help in discussing drone delivery, drone highway and drone swarm. This work was partially supported by JSPS KAKENHI Grant Number JP18K18434.

References

[1] Future of Life Institute, "Asilomar AI principles," https://futureoflife.org/ai-principles/, 2017.

[2] The IEEE Global Institute for Ethical Consideration in Artificial and Autonomous Systems, "Ethically aligned design: A vision for prioritizing wellbeing with artificial intelligence and autonomous systems, version 1," http://standards.ieee.org/develop/indconn/ec/autonomous_systems.html, 2016.

[3] ——, "Ethically aligned design: A vision for prioritizing wellbeing with artificial intelligence and autonomous systems, version 2," http://standards.ieee.org/develop/indconn/ec/autonomous_systems.html, 2017.

[4] The Conference toward AI Network Society, "Draft AI R&D guidelines for international discussions," http://www.soumu.go.jp/main_sosik/joho_tsusin/eng/Releases/Telecommunications/170728_05.html, 2017, (Tentative Translation).

[5] ——, "Report 2017: Toward promotion of international discussions on AI networking: Overview," http://www.soumu.go.jp/main_sosik/joho_tsusin/eng/Releases/Telecommunications/170728_05.html, 2017.

[6] ——, "Socioeconomic impact of AI networking: Preliminary assessment," http://www.soumu.go.jp/menu_news/s-news/01iicp01_02000067.html, 2017, (Attached Paper 3 of Report 2017: Toward Promotion of International Discussions on AI Networking) (in Japanese).

[7] K. Sekiguchi, K. Tanaka, and K. Hori, ""design with discourse" to design from the "ethics level"," in *Volume 206: Information Modelling and Knowledge Bases XXI:*, ser. Frontiers in Artificial Intelligence and Applications, T. W. Družovec, H. Jaakkola, Y. Kiyoki, T. Tokuda, and N. Yoshida, Eds. IOS Press, 2009, pp. 307–314.

[8] R. A. Finke, T. B. Ward, and S. M. Smith, *Creative Cognition*. MIT Press, 1992.

[9] H. A. Simon, *The Sciences of the Artificial, Third Edition*. MIT Press, 1996.

[10] H. Yoshikawa, "Introduction to general design theory," *Journal of the Japan Society of Precision Engineering*, vol. 45, no. 536, pp. 906–912, 1979, (in Japanese).

[11] ——, "General theory of design process," *Journal of the Japan Society of Precision Engineering*, pp. 19–24, 4 1981, (in Japanese).

[12] J. Lee and S. Han, "Knowledge-based configuration design of a train bogie," *Journal of Mechanical Science and Technology*, vol. 24, no. 12, pp. 2503–2510, Dec 2010.

[13] C. Chapman and M. Pinfold, "Design engineering—a need to rethink the solution using knowledge based engineering," *Knowledge-Based Systems*, vol. 12, no. 5, pp. 257 – 267, 1999.

[14] S. Myung and S. Han, "Knowledge-based parametric design of mechanical products based on configuration design method," *Expert Systems with Applications*, vol. 21, no. 2, pp. 99–107, 2001.

[15] Y. Afacan and H. Demirkan, "An ontology-based universal design knowledge support system," *Knowledge-Based Systems*, vol. 24, no. 4, pp. 530–541, 2011.

[16] T. Tomiyama, "Function allocation theory for creative design," *Procedia CIRP*, vol. 50, pp. 210–215, 2016, 26th CIRP Design Conference.

[17] K. Wang and J. V. Nickerson, "A literature review on individual creativity support systems," *Computers in Human Behavior*, vol. 74, pp. 139–151, 2017.

[18] K. Sekiguchi, "dfrome; website for design from the ethics level," https://www.dfrome.com, 2017.

[19] K. Nakakoji, "From interfaces to interactions: An overview of sighi (1001 sig nights)," *IPSJ Magazine*, pp. 202–203, 2 2007, (in Japanese).

[20] The Ethics Committee, The Japanese Society for Artificial Intelligence, "Open discussion," http://ai-elsi.org/archives/628, 5 2017.

[21] H. Yoshikawa, "Introduction to theory of service engineering: Framework for theoretical study of service engineering," *Synthesiology*, pp. 111–122, 4 2008, (in Japanese).

[22] K. Hori, "Do knowledge assets really exist in the world and can we access such knowledge?; knowledge evolves through a cycle of knowledge liquidization and crystallization," in *Intuitive Human Interfaces for Organizing and Accessing Intellectual Assets*, ser. Lecture Notes in Artificial Intelligence, G. Grieser and Y. Tanaka, Eds. Springer, 2004, pp. 1–13.

[23] R. Řehůřek and P. Sojka, "Software framework for topic modelling with large corpora," in *Proceedings of the LREC 2010 Workshop on New Challenges for NLP Frameworks*. Valletta, Malta: ELRA, May 2010, pp. 45–50, http://is.muni.cz/publication/884893/en.

[24] Neuron Data Inc., "Neuron data elements environment v2.1—getting started," http://www.imn.htwk-leipzig.de/ sunpool/software/ee21/getstart/getstart.pdf, 1996.

[25] M. Nickel, K. Murphy, V. Tresp, and E. Gabrilovich, "A review of relational machine learning for knowledge graphs," *Proceedings of the IEEE*, pp. 11–33, 1 2016.

[26] Q. Le and T. Mikolov, "Distributed representations of sentences and documents," in *Proceedings of the 31st International Conference on Machine Learning - Volume 32*, ser. ICML'14. JMLR.org, 2014, pp. II–1188–II–1196.

[27] M. Terada, "Legal study on drone highway," *Information Network Law Review*, pp. 31–49, 3 2018, (in Japanese).

[28] A. Goodchild and J. Toy, "Delivery by drone: An evaluation of unmanned aerial vehicle technology in reducing co2 emissions in the delivery service industry," *Transportation Research Part D: Transport and Environment*, vol. 61, pp. 58–67, 2018.