Visualizing Characteristic Interdisciplinary Research Collaborations Among Departments in a University

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Abstract

This research-in-progress paper presents a novel visualization approach to facilitate understanding of interdisciplinary collaboration within a university using a large-scale dataset of research grant projects in Japanese universities. First, we construct a network of departments in a target university, and then visualize the activeness of inter-departmental collaborations using member information of research projects. Second, to compare research features among universities, we quantify the difference in the frequency of research field combinations between the target university and other universities. Collaborations that have characteristic research field combinations are then highlighted in the network, which can be useful for the target university's research promotion strategies. We present a case study at the University of Tokyo to validate the effectiveness of our approach. To enhance our visualization's advantage, we also demonstrate that the average amount of research grants that the characteristic research field combinations received is significantly higher than those of field combinations that are prevalent among several universities.

Introduction

Interdisciplinary collaborations have become increasingly important for providing innovative solutions to complex problems. Research administrators at a university often make efforts to analyze the performance of its research institutes to create an interdisciplinary team from different departments. Understanding the characteristics of research at the university compared with other universities is also crucial for choosing research promotion strategies. However, there is no established visualization framework for such a comparison of research features among universities.

Previous studies have defined measures of interdisciplinarity for several academic entities, such as journals and authors. For example, Rodríguez (2017) proposed a citation-based indicator for classifying scientific journals into four classes based on their degree of interdisciplinarity. Zhang et al., (2020) used a co-author network to assess the interdisciplinarity of each researcher. To examine the status of collaborations across research topics, Rafols and Meyer (2010) evaluated the degree of interdisciplinarity of papers published in bioscience and visualized them on a two-dimensional plane. Some studies focused on using the attributes of researchers listed in individual research projects. L. Zhang et al., (2018) analyzed the diversity of disciplines estimated from the authors' varied affiliations. Abramo, D'Angelo, and Di Costa (2012) analyzed collaboration frequencies among researchers from different fields to identify frequent field combinations. Similarly, Uddin, Imam, and Mozumdar (2020) constructed a network in which each node represents a discipline, while an edge between two nodes represents the participation of corresponding disciplines in grant projects. The line of these science mapping research projects has the potential to be extended to institutional research in a university.

In this research-in-progress paper, we present a novel visualization approach to facilitate understanding of a university's collaboration characteristics in interdisciplinary research. Our study uses a large-scale dataset of research grant projects in Japan. First, we construct a network of departments using member information of research projects to show the activeness of inter-departmental collaborations. Second, to compare universities, we quantify the difference in frequency of research field combinations between the target university and other universities. Collaborations that have characteristic research field combinations are then highlighted in the network, which can be useful for the target university's research promotion strategies. A case study at the University of Tokyo is presented in this paper to validate the effectiveness of our approach. We also investigate the difference in the average amount of research grants received by field combinations judged as characteristic and those deemed common.

Dataset

Our study requires a dataset containing collaborative research project information, including member affiliations and research field labels. To construct such a dataset, we chose KAKEN[1] as an information source. KAKEN is the database of Grants-in-Aid for Scientific Research projects granted by the Ministry of Education, Culture, Sports, Science and Technology and the Japan Society for the Promotion of Science for research projects in all fields in Japan. Among KAKEN research projects from fiscal year (FY) 2004 to FY 2017, we extracted the projects that have at least two researchers and classified them as "collaborative research projects." In KAKEN, each research project is classified into a single field category by the Principal Investigator according to the application year's list of categories. We first manually integrated these field categories, which differ from year to year, into the 13 field labels of the list as of 2017. Although field labels are provided to research projects in KAKEN, and not to individual researchers, our study requires collaborators' field information similar to that used in Abramo, D'Angelo, and Di Costa's study (2012). Thus, we assigned the field label of a research project to the project's Principal Investigator so that each researcher can be associated with one or more field labels. The resulting dataset consisted of 112,722 research projects, 4,054 domestic institutions, and 130,733 unique researchers.

Measures of a university's collaborative research

Activeness of collaborative research

We first aim to investigate the activeness of collaborations between different departments in a target university. Let U be the set of all universities in the dataset. The set of departments in a target university $u \in U$ is denoted by Ω_u. Let $T^u_{d,d'}$ be the set of research projects, which contain at least one researcher from department $d \in \Omega_u$ as well as at least one researcher from department $d' \in \Omega_u$. We represent how active the inter-departmental collaborations between departments d and d' using the cardinality of the project set as follows:

$$Active_{collab}(d, d') = \left|T^u_{d,d'}\right|. \quad (1)$$

Although this simple count-based measurement contributes to finding frequent patterns of inter-departmental collaborations "within" a target university, it cannot reveal how characteristic each pattern is, "compared with" other universities. We solve this problem in the following subsection.

[1] https://kaken.nii.ac.jp/en/

Activeness of characteristic interdisciplinary collaborative research

To characterize features of the university's inter-departmental collaborations, we define a combinatorial set of field categories of researchers participating in a single research project as a "*field combination*." For example, suppose a project is conducted by four researchers whose fields are computer science (CS), humanities (H), CS, and engineering (E), respectively, we can extract from this project the following field combination; (CS, H, E). Note that if a researcher has multiple labels, all the labels are considered to create a combination. We assume that if a certain field combination occurs frequently in a target university compared with other universities, the corresponding topic can be the characteristic of the university. Specifically, the characteristic of a field combination c for a target university $u \in U$ is quantified using the following measure:

$$Measure_{character}(u,c) = t\_ratio(u,c) - \frac{1}{|U-\{u\}|}\sum_{j\in U-\{u\}} t\_ratio(j,c)\,, \qquad (2)$$

$$t\_ratio(j,c) = \frac{\text{Number of research projects corresponding to field combination } c \text{ at university } j}{\text{Total number of research projects at university } j}.$$

A large value of $Measure_{character}(u,c)$ means the field combination c can represent characteristic collaboration at university u.

Next, we quantify the activeness of "characteristic" interdisciplinary collaborations between departments in a target university $u \in U$. The field combination extracted from project $t \in T^u_{d,d'}$ is denoted by $c(t)$. For two departments d, d', focusing on how many of their collaborations were produced by characteristic field combinations, we compute the following activeness measure:

$$Active_{character}(d,d') = \sum_{t\in T^u_{d,d'}} g(c(t)) \;(3),$$

$$g(c) = \begin{cases} Measure_{character}(u,c), & \text{if } Measure_{character}(u,c) > \mu_{u,c} + \sigma_{u,c}, \\ 0, & \text{if } Measure_{character}(u,c) \le \mu_{u,c} + \sigma_{u,c}, \end{cases}$$

where $\mu_{u,c}$ and $\sigma_{u,c}$ are the mean and the standard deviation of the values that satisfy $Measure_{character}(u,c) > 0$, respectively. If $Measure_{character}(u,c(t)) > \mu_{u,c(t)} + \sigma_{u,c(t)}$, the project t is defined as a "characteristic" interdisciplinary collaboration, and its activeness score contributes to $Active_{character}(d,d')$. A large value of $Active_{character}(d,d')$ means that the two departments d and d'actively collaborate, especially in research topics of characteristic field combinations for the university. Using this measurement, we can easily find which department pair conducts collaborations that can be features of the university.

Results

Visualization based on network construction

To verify the effectiveness of the proposed method, we present a case study at the University of Tokyo, which has 13 research departments. We first constructed two networks whose nodes and edges are departments and their collaboration relationships, respectively. In each network, nodes and edges are weighted using Eq. (1) or Eq. (3). Note that for $d = d'$, each measure represents the activeness of "intra-departmental" collaborations in department d, which was

used as node weights. Figure 1 shows the network weighted using Eq. (1), in which each edge/node is colored dark when the corresponding weight is high, with a light color used when the value is low. The figure shows that most of collaborations occur within departments (i.e., $d = d'$) and that many collaborative research projects are conducted within the Graduate School of Medicine compared to other departments. Figure 2 shows the network weighted using Eq. (3), in which the edge/node is colored, similar to Fig. 1. From Fig. 2, we can see the following two trends: (a) the Graduate School of Engineering actively conducts characteristic interdisciplinary collaboration within the department; and, (b) the Graduate School of Engineering and the Graduate School of Frontier Sciences actively collaborate in research projects belonging to characteristic field combinations.

Although we found from Fig. 1 that a number of collaborative research projects are conducted within the Graduate School of Medicine, Fig. 2 implies that their research field combinations are similar to other universities. For the Graduate School of Science, Fig. 1 shows that the number of collaborative research projects within the department is not large, while Fig. 2 indicates that researchers in the Graduate School of Science conduct many "characteristic" interdisciplinary collaborations within the department. We can consider that this department has the potential to create interdisciplinary collaboration teams with other the departments.

In addition, Table 1 shows the field combinations evaluated as characteristic interdisciplinary collaborations, sorted in descending order of $Measure_{character}$. We can see that environmental science/engineering is the most characteristic field combination in the University of Tokyo. The table shows that engineering is included in the higher rank of field combinations. We can confirm that the Graduate School of Engineering, to which many researchers assigned under the Engineering label are considered to belong, indeed has darker coloration of nodes and edges from Fig. 2. These findings will facilitate mapping a strategy to promote characteristic collaborations in the university.

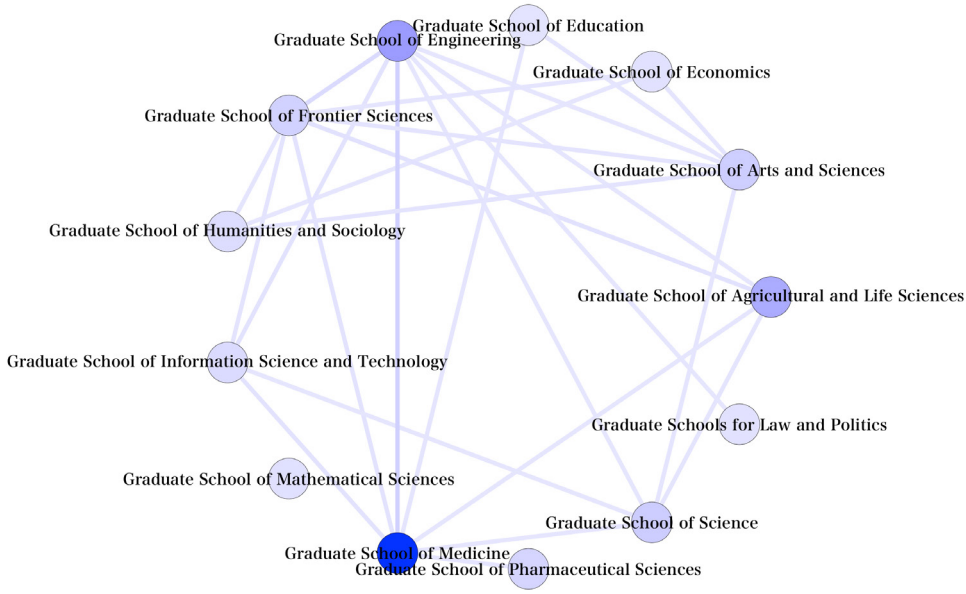

Figure 1. Visualization of the activeness of research collaborations based on Eq. (1).

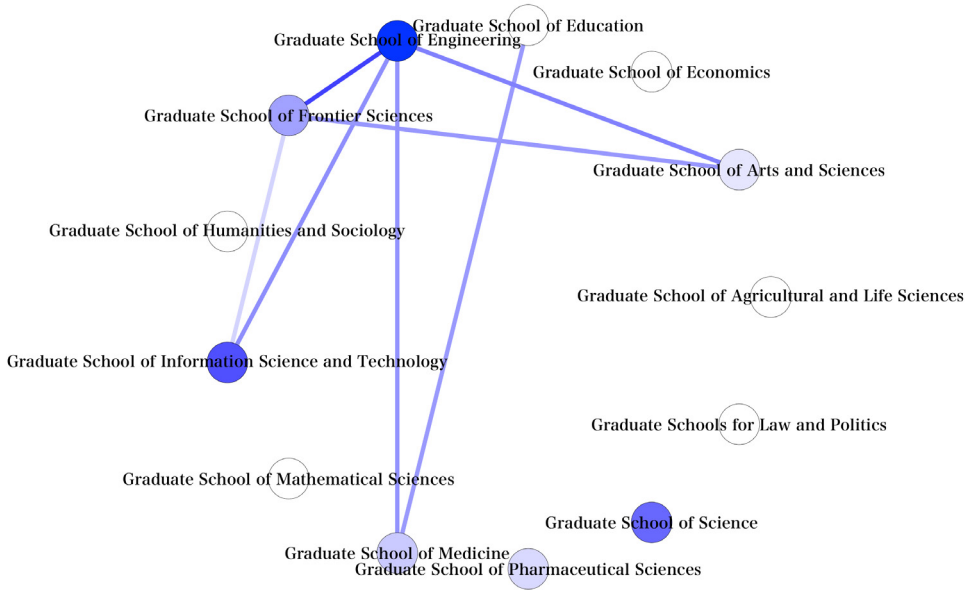

Figure 2. Visualization of the activeness of "characteristic" collaborations based on Eq. (3).

Table 1. Characteristic field combination in the University of Tokyo.

Rank	*Field combination*
1	Environmental science / Engineering
2	Interdisciplinary science and engineering / Engineering
3	Complex systems / Medicine, dentistry, and pharmacy / Chemistry
4	Interdisciplinary science and engineering / Mathematical and physical sciences
5	Complex systems / Medicine, dentistry, and pharmacy / Biological Sciences
6	Interdisciplinary science and engineering / Mathematical and physical sciences / Engineering
7	Interdisciplinary science and engineering / Chemistry / Engineering
8	Engineering / Informatics
9	Biology / Medicine, dentistry, and pharmacy / Biological Sciences
10	Environmental science / Mathematical and physical sciences

The impact of characteristic interdisciplinary collaborations on grant budgets

We further conducted in-depth analyses of the "characteristic" interdisciplinary collaborations found by our approach. Research projects in KAKEN were provided with budgets, whose amounts differ from one another. In this experiment, we compare the budgets' amounts between the research projects that are considered to be characteristic interdisciplinary collaborations and those that are not. Our research question here is: *Can characteristic interdisciplinary collaborations obtain more research budgets than non-characteristic ones?*

Given that the range of budget allocations for research projects varies, depending on the grant application categories, this experiment used only research projects in the category of *Grant-in-Aid for Scientific Research (B)*, which generally presupposes collaboration with multiple researchers. Projects in Grant-in-Aid for Scientific Research (B) are supported by budgets

ranging between 5 to 20 million yen. The average of the allocations for research projects belonging to different types of collaboration is shown in Table 2. We used the Mann-Whitney U test to examine whether there is a difference between the two groups. The two-sided test showed that the significance probability p was $p = 0.019 < 0.05$. Interestingly, it is demonstrated that the budget average amount allocated to the research projects judged as characteristic is significantly higher than that allocated to the research projects considered common.

Table 2. Comparison of average amounts of budget allocated to projects.

	Judged as	
	characteristic	*common*
Number of research project*s*	45	131
The average of the allocations (yen)	16,650,666	15,786,564

Conclusion

This research-in-progress paper proposed a novel visualization that facilitates better understanding of interdisciplinary collaborations within a university. We constructed a network representing the activeness of inter-departmental collaboration within a target university. We then found the characteristic field combination in the target university, and the activeness of the characteristic interdisciplinary collaboration is represented in the same network form. In addition, we demonstrated that the average of research grants that the characteristic research field combinations received is significantly higher than that obtained by common ones. In future work, we will apply the method to other research institutions for large-scale comparisons. We will also develop an interdepartmental collaborator recommendation system based on the proposed method like in our previous study (Takahashi, Tango, Chikazawa, & Katsurai, 2020).

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