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Descriptions of Spatial Operations – Recent Approaches and Community Feedback*

Barbara Hofer[1], Johannes Brauner[2], Mike Jackson[3], Carlos Granell[4], Armanda Rodrigues[5], Daniel Nüst[6], Stefan Wiemann[2]

[1]Interfaculty Department of Geoinformatics, University of Salzburg, Austria, barbara.hofer@sbg.ac.at

[2]Professorship of Geoinformation Systems, Technische Universität Dresden, Germany, johannes.brauner@tu-dresden.de , Stefan.wiemann@tu-dresden.de

[3]Nottinghan Geospatial Institute, University of Nottingham, United Kingdom, mike.jackson@nottingham.ac.uk

[4]Institute of New Imaging Technologies, Universitat Jaume I, Spain, carlos.granell@uji.es

[5] NOVA LINCS, Departamento de Informática, Universidade Nova de Lisboa, Portugal, a.rodrigues@fct.unl.pt

[6]52°North GmbH, Münster, Germany, d.nuest@52north.org

Abstract

Progress in the technical provision of spatial operations as loosely-coupled interoperable web services requires a corresponding development of standardisation in their description. Operation discovery, usage and interpretation of results require more information on what a spatial operation does than just their input and output interface specifications. Geooperators and WPS profiles have been proposed for addressing operation descriptions for different

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operational perspectives. Geooperators have been developed mostly for supporting operation discovery through defining alternative perspectives such as a geodata, legacy GIS, formal or technical perspective. These act as filters in the discovery process. WPS profiles provide a hierarchical approach to define the concept underlying an operation and, in more specific profiles, the syntactic interface of the operation. Both approaches require community engagement for reaching an agreed set of documented operations. We report on a discussion of these approaches and the larger framework of a geoprocessing community platform from a workshop held at the AGILE International Conference on Geographic Information Science in Lisbon in 2015. At the workshop two presentations provided insights in different contexts of use of online geoprocessing. After detailed introductions to the two operation descriptions approaches, two breakout sessions were held. In the breakout sessions operation descriptions and technical developments in the field were discussed. This article summarizes the discussion that took place at the workshop with the intention to involve the extended community in the discourse on operation descriptions.

Keywords: online geoprocessing, WPS profiles, geooperators

1. INTRODUCTION

Geoprocessing on the web refers to interoperable services for ad-hoc data processing and analysis. The usage of loosely-coupled interoperable web services for spatial analysis is increasing only slowly (Lopez-Pellicer, Rentería-Agualimpia et al. 2012, Hofer 2014). One of the issues that particularly requires further development, as they are fundamentally important for reusing services, is the detailed specification of spatial operations. Questions that have been addressed in the context of spatial data such as documentation, discovery and exchange need to be discussed for spatial operations as well.

In the Web Processing Service (WPS) interface standard, processes are described by title, abstract and input and output of the operation (OGC 2015b). The specification of input and output is syntactical with a focus on data exchange formats. As has been previously documented (Lutz 2007, OGC 2012, Schade, Ostländer et al. 2012), these pieces of information are not sufficient to successfully discover operations, use them and interpret results. Elements of operation descriptions that support discovery include: the means to compare operations, search based on underlying concepts, relationships between operations. When an operation has been identified, users need to know for which

analysis task it can be applied meaningfully and how to use it. Meaningful application of spatial operations can be reached by assessing the match between data and operation on a semantic level (Härtwig, Müller et al. 2014, Stasch, Scheider et al. 2014). Analysis results need to be interpreted based on provenance or lineage information, stating how the results were generated and which functionality was applied to the input data.

Two recent approaches for extended operation descriptions are geooperators (Brauner 2015) and WPS profiles (Müller 2015). Geooperators support discovery and comparison of processing functionality; WPS profiles have been introduced to reduce implementation uncertainty of operations. These two approaches need to be made known in the geoprocessing community and be improved based on feedback from the community. A registry of geoprocessing functionality is required for both of the presented approaches to extended operation descriptions. Such a registry could be included in a community platform for the geoprocessing field. An existing community platform that serves the intended purpose is the Geoprocessing Appstore (Henzen, Brauner et al. 2015). For example, the Appstore already includes a browser that is based on geooperators and demonstrates discovery based on this approach.

The intention to stimulate exchange with the geoprocessing community about the proposed approaches for operation descriptions and a community platform was the motivation for a one day workshop with the title “Geoprocessing on the Web – Science-driven and Community-driven”. The workshop was held at the 18th AGILE conference in Lisbon, Portugal on June 9, 2015.

The workshop consisted of three main parts: in the first part the keynote and a presentation provided insight in different contexts of use of online geoprocessing and the current state of development. The second part focused on input for the discussion about community building required in the field and feedback on extended operation descriptions. The Geoprocessing Appstore was presented as a geoprocessing community platform that can be shaped based on feedback. The following three presentations focused on details of geooperators and WPS profiles and data fusion as exemplary field of application of extended operation descriptions. These two parts were designed to prepare the participants for the breakout sessions in the third section of the workshop. Two breakout sessions were held, one focusing on technical developments in the field and the second one related to extended operation descriptions, which is the focus of this paper.

The discussion about extended operation descriptions that was initiated at the workshop needs to be continued in order to reach consensus in the community. This paper summarizes the content presented at the workshop and the discussions about the presented approaches with the intention to involve the extended community in the discourse. Section 2 summarizes the presentations

given at the workshop and section 3 introduces geo-operators and WPS profiles in more detail. The general discussion with workshop participants and results from the breakout session are presented in section 4. Conclusions in section 5 complement the report.

2. PRESENTATIONS HELD AT THE WORKSHOP ON GEOPROCESSING ON THE WEB

In this section we summarize the content of the two parts of the workshop that provided the basis for the subsequent discussion with the workshop participants: part 1 on the state of the art in the field and part 2 on approaches to improve discovery and usability of geoprocessing functionality. The presentations we refer to are available online: http://purl.org/net/agile-geoprocessing-15 [last accessed 20151209].

2.1. Part 1: State of the Art in Online Geoprocessing

Keynote: Towards citizen-driven, contextualized geo-processing, Carlos Granell (Universitat Jaume I of Castellón, Spain)

Carlos Granell gave an overview on approaches to online geoprocessing in his keynote. First he noted that many scientific disciplines have been affected by the improved availability of data and GIScience is not an exception (Lee and Kang 2015). Approaches to geoprocessing can be science-driven, data-driven, and citizen-driven. In science-driven geoprocessing, development of models, composition of services to workflows, and the analysis itself are in the centre. Data-driven geoprocessing starts from huge amounts of data that influence the development of models. Citizen-driven geoprocessing focuses on user perspectives and then works on datasets and their analyses. This categorization will help in understanding different approaches and eventually lead to an integration of approaches, for example in the context of city management, where different forces (geoprocessing services, continuous streams of data, citizens) are equally important. The establishment of well-defined spatial operations is of great importance in science-driven geoprocessing since these operations play a fundamental role for building complex geoprocessing chains. Even though in data-driven and citizen-driven geoprocessing the focus is put on data and user needs respectively, availability of spatial operations becomes even more necessary to mainstream and leverage such spatial operations in varied applications and use cases, other than simply in traditional geoprocessing composition scenarios.

Frameworks for geoprocessing on the web with R, Daniel Nüst (52°N GmbH, Germany)

Daniel Nüst presented current activities at 52°North with sensorweby (http://blog.52north.org/2015/04/22/advanced-time-series-analysis-on-the-web-with-r/ [last accessed 20151209]) and WPS4R (Hinz, Nüst et al. 2013). Sensorweby and WPS4R aim at facilitating the work of scientists by allowing them to build on top of their existing skills in R (the R software is widely used in the research community and a powerful tool for data analysis). Sensorweby is an integration of the app development tool Shiny and the 52°North JavaScript Sensor Web Client; it allows the creation of a user interface and plots based on R code using time series published through an interoperable standardized web service interface, the OGC Sensor Observation Service (SOS). WPS4R is a framework to deploy R scripts with a few lines of annotations on the 52°North WPS server as interoperable geoprocesses.

Nüst introduced an example of reproducible scientific analysis with WPS4R (Nüst, Václavík et al. 2015). Experts had derived a world-wide classification of land systems into 12 classes (Václavík, Lautenbach et al. 2013) based on over 30 global datasets. In the provided browser application users can reproduce and assess the experts' work by altering parameters such as the number of classes that are to be differentiated in the resulting map in a simple web form. Then they can execute the altered process online without downloading data or software. The application then creates a result with fewer or more classes based on a machine learning algorithm. The created result does, however, not contain any interpretation of the created classes, which is the major contribution of the experts in their work. The class generating algorithm is successfully implemented as a service, but the question remains whether its users have to have knowledge to meaningfully interpret the results. Also the reproducibility is limited, because changing the input datasets, for example adding other datasets or selecting from the available ones is future work.

2.2. Part 2: Fostering Discovery and Usability of Geoprocessing Functionality

Geoprocessing Appstore, Johannes Brauner (Technische Universität Dresden, Germany)

The Geoprocessing Appstore is a platform offered to the geoprocessing community for sharing processing functionality, providing knowledge about geoprocessing, and acting as a central repository or catalogue for discovering geoprocessing functionality (Henzen, Brauner et al. 2015). This concept has its origin in the Persistent Interoperability Test-bed (PTB) which aimed to facilitate interoperability between OGC-based services, by establishing a service-oriented platform with stable instances of geoprocessing services ready to be used in

applications and experiments (Jackson, Hobona et al. 2011). The Geoprocessing Appstore goes beyond the PTB in that it offers functionality for the documentation of workflows, for the provision of functionality for frequently performed tasks and for the exchange of best practice examples. It furthermore rests on the moving code paradigm for geoprocessing (Müller, Bernard et al. 2010, Müller 2013) by providing executable code packages that can be sent to be executed at or close to the dataset instead of transporting the dataset to the processing service.

Geooperators, Johannes Brauner (Technische Universität Dresden, Germany)

In desktop GIS, current discovery mechanisms for geoprocessing functionality are not satisfactory (Brauner 2015). Discovery of geoprocessing services in spatial data infrastructures (SDI) is even less complete as there are no central catalogue mechanisms, nor does a Google search lead to satisfactory results. The concept of geooperators provides an approach to improve discoverability of geoprocessing functionality and also an approach to describe and formalize information about exchangeability of geoprocessing functionality (Brauner 2015). Both approaches are essential requirements for exploiting geoprocessing services in SDI. Geooperators are formalized concepts for geoprocessing functionality and are defined as representations of well-defined functionality, either defined by its implementation in software or respective literature.

WPS Profiles, Barbara Hofer (University of Salzburg, Austria)

The revised OGC specification of WPS includes a proposal for extended WPS profiles, which are meant to detail the characteristics of functionality provided in services (OGC 2015b). WPS profiles aim to harmonize implementations of operations across products and provide documentations of operations (Müller 2015). Agreement needs to be reached on concepts of functions and their implementations. For describing operations, WPS profiles follow a hierarchical structure of process concepts, generic profiles and implementation profiles that capture semantic and syntactic properties of geoprocessing functions (Müller 2015).

Geoprocessing for Data Fusion, Stefan Wiemann (Technische Universität Dresden, Germany)

Stefan Wiemann talked about geoprocessing for data fusion. When integrating datasets from different sources, a variety of operations potentially need to be applied: change detection, measurement of spatial and thematic properties, topology checks, index updates, feature generalization, etc. When putting together a workflow for reaching a product that adheres to defined quality standards, choices on which operations to use in which sequence need to be made. Detailed descriptions of spatial operations, including semantics and similarity among operations, are of importance in such an analysis workflow.

3. APPROACHES TO OPERATION DESCRIPTIONS AND EXCHANGE

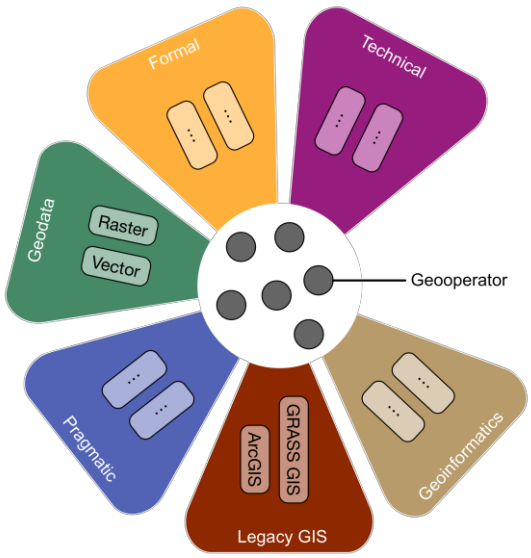
As stated above, the main objectives of the workshop were to foster community exchange and to receive feedback on the recent approaches to operation descriptions. Geooperators and WPS profiles are therefore introduced in detail in this section of the paper. Section 3.3 on similarities and differences between the two approaches was added to the paper after the workshop.

3.1. Geooperators

Discovery in legacy GIS is shaped by the ways in which the tools organize operations. For instance, ArcGIS' organizes operations in toolboxes; as a consequence, keyword search only lists 35 tools using the keyword *vector*. On the contrary, GRASS separates operations based on the underlying geodata model which is reflected in the module hierarchy.

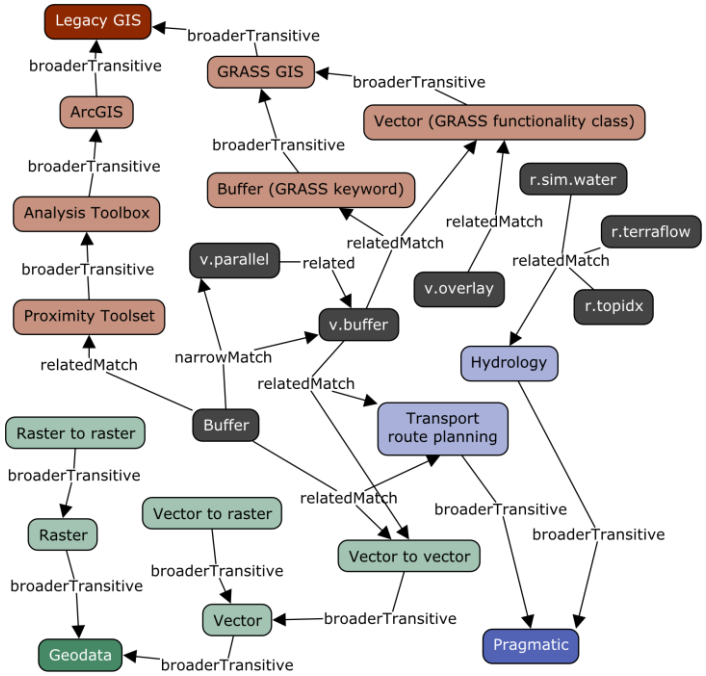
Geooperators are designed to support discovery and comparison of operations through including various views on operations in the discovery process. A geooperator thereby is a geospatial analysis or transformation operation that is usually implemented in software; geooperators are provided with a unique identifier. Geooperator properties are formalized as hierarchical geooperator categories, taking multiple perspectives into account. For instance, a perspective consisting of hierarchical properties related to geodata attributes, e.g. vector or raster data model. An overview of identified perspectives and top-level categories is given in Figure 1. Thus, by choosing a perspective and subsequently underlying categories, discovery of geooperators is facilitated.

Figure 1: Different Perspectives on Geooperators.



To improve comparability and subsequently exchangeability of geooperators, geooperators are linked to other geooperators providing similar functionality. Overall, geooperators, categories, and perspectives are interlinked and form a network, which is conceptualized as a concept map (see Figure 2).

Figure 2: Geooperator Concept Map.



To allow for human and machine readability and application in SDI, the geooperator concept map is formalized as a geooperator thesaurus encoded in SKOS (Simple Knowledge Organization System) usually used in Semantic Web contexts. SKOS provides multiple views on its content, e.g. HTML (Hypertext Markup Language) for humans and RDF (Resource Description Framework) for machines. The prototype is available at http://purl.org/net/geooperators [last accessed 20151209]. For usage in SDI, the geooperator definitions can be injected on the fly as semantic annotations in WPS process descriptions.

3.2. WPS Profiles

The recently published WPS 2.0 Interface Standard of the Open Geospatial Consortium includes a revision of the asynchronous execution mechanism of WPS, introduces nested inputs and outputs missing in WPS 1.0, foresees sections for documentation, keywords for inputs and outputs, and introduces extended WPS profiles (OGC 2015b). From this list of changes alone, the importance of input and output parameters and operations descriptions is

apparent. Nevertheless, exchange of analysis functionality requires potential users also to have knowledge about what operations do and how they function. This is addressed by WPS Profiles.

WPS profiles foresee a hierarchy of profiles: process concept, generic profile and implementation profile. Process concepts provide a documentation of what an operation does (purpose, methodology, properties) typically in form of HTML documents (OGC 2015b). Concepts can form a hierarchy by themselves as different subtypes of operations exist. For example, Euclidean distance buffer and geodesic distance buffer are both subtypes of a buffer operation. Generic profiles provide identifiers for operations, add the abstract interfaces to operations, and describe how operations work. They will contribute to resolving naming heterogeneity and may add details on the process mechanics, such as computational precision (Müller 2015). The implementation profile extends the generic profile with data exchange formats and non-functional parameters such as size limitations for inputs.

The process profiles are linked to specific implementations by metadata tags in the *DescribeProcess* document. Profile providers can choose which profiles they want to specify as the specification cannot force the preparation of all three profiles. There is no registry for these profiles, which means that profile providers need to reference their profiles independently from other potentially existing profiles.

3.3. Differences and Similarities of WPS Profiles and Geooperators

In the discussion of geooperators and WPS profiles during the workshop the need for showing how they are related or different became apparent. The following table highlights some characteristics of the two approaches (table 1). As the motivation behind the two approaches is different, a definitive alignment may not be feasible. In addition, strengths and weaknesses of the two approaches will become clearer after field tests.

Table 1: Summary of Characteristics of Geooperators (Brauner 2015) and WPS Profiles (Müller 2015).

Geooperators	
Main Objective	The main objective of geooperators is to support discovery and comparison of geoprocessing operations.
Approach	The approach of geooperators is to capture different perspectives on operations and to establish links between related operators. A geooperator thesaurus makes these components machine-usable for discovery and comparison.

Main Contribution	The contribution of geooperators is a vocabulary of properties of functions and a formalism for representing the links between operations, which makes the descriptions machine-usable.
Implementation	A geooperator browser demonstrates discoverability and comparison of geoprocessing operations based on the proposed formalism (http://purl.org/net/geooperators [last accessed 20151209]).
WPS Profiles	
Main Objective	The main objective of WPS Profiles is to reduce implementation uncertainty of geoprocessing functionality. They aim at providing a foundation for the implementation of geoprocessing functions.
Approach	WPS profiles provide a hierarchy of profiles for a technical description of implementations of geoprocessing functions. The hierarchy of profiles is formalised whereas the content of the profiles is prepared for use by human users. The interface specifications are the basis for deriving WPS profiles.
Main Contribution	WPS profiles provide a structure for technical specifications of operations to implementers of such functions.
Implementation	The preparation of profiles and the implementation of a catalogue are future work (Müller 2015).

4. COMMUNITY FEEDBACK AND DISCUSSION

This section summarizes the general discussion with all workshop participants (section 4.1) and ways forward identified during the breakout session on operation descriptions (section 4.2).

4.1. General Discussion during the Workshop

The starting point of the discussion was questions posed to workshop participants. These questions concerned their views on a community platform like the geoprocessing appstore and required improvements of geooperators and WPS profiles. Specific questions asked were:

- How can the community best be involved in building a community platform?
- Which functionality is missing in the geoprocessing appstore?
- How to stimulate contributions of geooperator descriptions from the community?
- Are the suggested perspectives for geooperators complete or are additional perspectives required?
- Is it possible to achieve agreement on concepts of geoprocessing functions as required for WPS profiles?
- What are the sources of literature from which process profiles may be identified and implementation details determined and agreed upon?

The feedback on operation descriptions from workshop participants was that they seem relevant; discovery, comparability and cataloguing of spatial operations can be improved with presented approaches to operation descriptions. However, there are different views among the workshop attendees on how the community could be motivated to contribute to the descriptions. The challenge for progressing with operation descriptions is, on one hand, to achieve a consolidated approach to operation descriptions and, on the other hand, to ensure these descriptions are used by the community.

There was little feedback regarding possible contributions of operation descriptions through the community. One participant stated that he had the impression that he cannot contribute to operation descriptions. This is surprising as operation descriptions cover knowledge which GIS experts should readily have to a large degree.

The discussion about the completeness and quality of operation descriptions themselves remained on rather a general level. Questions raised concerned the requirements of different users of geospatial operations. Expert users do require a highly detailed description of operations and should avoid using black box operations. General users rather require a synthesis of larger numbers of operations with similar functionality. Both approaches to documentation of operations – geooperators and WPS profiles – need to mature or even be replaced in order to become community accepted solutions.

WPS profiles may be used as means to agree on geoprocessing functionality across the community in similar ways to operations defined in ISO standards (ISO/CEN 2006). The workshop participants doubted that agreement on generic profiles of geoprocessing functionality is realistic. If semantic data interoperability is already hard, how can interoperability for operations be feasible? Besides that, the acceptance of WPS profiles is questionable without an effort to build a community around them, despite the fact that they are part of the WPS 2.0.

The problems mentioned by workshop participants in their work with online geoprocessing were largely of a technical nature. Data-driven geoprocessing and issues related to working with big data, like parallelization of algorithms and processes, were discussed in the breakout session focusing on technical developments. Some of the mentioned challenges are missing natural ways to split up some geodata for distributed processing, or a lack of “automatic scalability” in scientific software which is used for prototyping. A wish for a WPS cookbook was also brought forward to ease the usage of this technology. The need for semantically enriched and formalized operation descriptions was not clearly identifiable in daily problems of workshop participants.

4.2. Advancing Spatial Operation Descriptions – Results from the Breakout Session

The concluding part of the workshop was breakout sessions for an in-depth discussion of topics of interest to the workshop participants. The breakout session on extended operation descriptions built on general points of discussion summarized in section 4. One of the main questions that took shape during the discussion was how to involve the community in advancing operation descriptions and platforms for community exchange. The ways forward that were identified in the breakout session are listed below.

Catchy examples: examples that clearly demonstrate the value of operation descriptions are required. Such examples can help the communication of the relevance of operation descriptions and should relate to problems of users of online geoprocessing. The drivers for the examples are problems that arise when operation descriptions are missing;

Engagement of contributors of operation descriptions: participants assume that GIS experts have the expertise to provide descriptions of operations they are using. If contributors are recruited, clear guidelines on what they should provide are required. The preparation of concise guidelines may require a synthesis of existing approaches to operation descriptions. In addition, the added value of operation description needs to be obvious for contributors;

Meta-analysis of existing algorithmic approaches: certain scientific GIS domains benefit from a meta-analysis on the publications, implementations and work on a certain topic, e.g. cartographic generalization, to derive a commonly used set of algorithms and approaches. However, such analysis is time-consuming and not applicable to every GIS (problem) domain;

Focus on user communities: addressing specific user communities may facilitate the preparation of examples and generate interest in operation descriptions. In analogy, City GML is presented as an integration platform for specific communities in the context of smart cities (OGC 2015ab).

Promotion of the Geoprocessing Appstore: open issues about the appstore are of similar nature regarding requirements and contributions of the community. Unless a range of operands is available in the appstore, usage will be limited; the fewer contributions are made on the platform, the longer it will take to reach a critical number of developments. In the context of operation descriptions, the appstore could be a demonstrator of best practice examples and support the practical usage of the descriptions.

5. CONCLUSIONS

The Geoprocessing Appstore did not receive broad interest during the workshop. Referring to the diffusion of innovation by Rogers (1962), innovators start with the adoption of new developments, followed by early adopters and an early majority.

The late majority and laggards follow at a later moment in time whereas they round off the market share of a development. Given that web services have not yet reached acceptance by a late majority as is indicated by an analysis of Lopez-Pellicer, Rentería-Agualimpia et al. (2012), the time of a community around the Geoprocessing Appstore may not have come yet.

Both approaches to improve operation descriptions discussed in section 3 require community involvement. Diverse communities dealing with the wide topic of spatial analysis exist, but how these communities can be motivated to contribute operation descriptions is unclear. It is open, whether contributions should be sought in a discipline-oriented or technology-centered way and how consensus on operation descriptions could be reached within such communities.

The workshop was highly valuable for understanding the differences in the perspectives of researchers working on approaches towards operation descriptions and practitioners dealing with technical problems. Eventually these perspectives need to converge and the mutual benefits of operation descriptions need to be understood and exploited. At the current stage of development, stating requirements and problems are valuable contributions to advance the topic.

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