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Highlights

- Heterogenous Data Sources
- Control of Time-Delay Systems
- A Group Dynamic Perspective
- Coping with Data Inconsistencies

Discovering Thoughts, Inventing Future

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By Joshua Edem Agomor & Meda Saawah Appiah

Abstract- This research examines the problem of inconsistent data when integrating information from multiple sources into a unified view. Data inconsistencies undermine the ability to provide meaningful query responses based on the integrated data. The study reviews current techniques for handling inconsistent data including domain-specific data cleaning and declarative methods that provide answers despite integrity violations. A key challenge identified is modeling data consistency and ensuring clean integrated data. Data integration systems based on a global schema must carefully map heterogeneous sources to that schema. However, dependencies in the integrated data can prevent attaining consistency due to issues like conflicting facts from different sources. The research summarizes various proposed approaches for resolving inconsistencies through data cleaning, integrity constraints, and dependency mapping techniques. However, outstanding challenges remain regarding accuracy, availability, timeliness, and other data quality restrictions of autonomous sources.

Keywords: data, data amalgamation, data inconsistency, data dependencies, integrity constraints, schema.

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Coping with Data Inconsistencies in the Integration of Heterogenous Data Sources

Joshua Edem Agomor [α] & Meda Saawah Appiah [σ]

Abstract- This research examines the problem of inconsistent data when integrating information from multiple sources into a unified view. Data inconsistencies undermine the ability to provide meaningful query responses based on the integrated data. The study reviews current techniques for handling inconsistent data including domain-specific data cleaning and declarative methods that provide answers despite integrity violations. A key challenge identified is modeling data consistency and ensuring clean integrated data. Data integration systems based on a global schema must carefully map heterogeneous sources to that schema. However, dependencies in the integrated data can prevent attaining consistency due to issues like conflicting facts from different sources. The research summarizes various proposed approaches for resolving inconsistencies through data cleaning, integrity constraints, and dependency mapping techniques. However, outstanding challenges remain regarding accuracy, availability, timeliness, and other data quality restrictions of autonomous sources. Additional research is needed to develop more automated ways of reconciling inconsistencies from source data with the requirements of the global schema. The ability to provide high-quality integrated data is crucial for organizations to maximize the value of their information assets. This research aims to promote further investigation into semi-automated remediation of inconsistencies and leveraging source data quality metrics to aid the integration process. Overcoming inconsistencies is critical to enabling unified views and meaningful analytics from merged cross-organizational data.

Keywords: data, data amalgamation, data inconsistency, data dependencies, integrity constraints, schema.

I. Introduction

Data is raw facts (M. Chen et al., 2009). Having the same data in different formats and in many tables causes inconsistent data. Data integration, also known as data amalgamation, is the act of merging data from several sources into cohesive sets of information for operational and analytical reasons (Lenzerini et al., 2014). One of the fundamental components of the entire process of data management is integration of data, its primary goal is to create clean, consistent, and consolidated data sets that meet the information requirements of various organization end users. An integrated view of diverse databases is referred to as a global schema. However, an important part of creating a global schema is identifying common types of information from the various local schemas. The world wide web has facilitated a prevalent access to autonomous, distributed, and dissimilar sources of data and has gotten worse. However, external users can now access an escalating quantity of records or databases, particularly the publicized ones on the internet and media. When converting user requests to queries across multiple data sources with varying data quality, this process does not take the quality of the data sources into consideration (Hariri, Fredericks, & Bowers, 2019).

In terms of dealing with inconsistent data in information amalgamation or integration, there are essentially two methods (DeCastro-García, Muñoz Castañeda, Fernández Rodríguez, & Carriegos, 2018). The first method in nature which is also based on domain-specific data cleaning, however, it is bureaucratic, and alteration methods used on sources' data that have been obtained. Declarative is used as the second strategy (DeCastro-García et al, 2018). In essence, several studies propose methods for giving insightful responses even when a database does not adhere to its integrity criteria (Cao, Lu, & Wen, 2019).

One of the most difficult aspects of data amalgamation is dealing with discrepancies or data being inconsistent (Lenzerini, Salaria, & Roma, 2014). The data integration systems in this work are differentiated by having a global schema-based design and a variety of sources. The sources include the relevant data, but the global schema conceals, integrates, and displays a virtual picture of the underlying sources. A mapping establishes connections between data sources and global schema components. Inconsistency may occur because sources may contain data that, when combined with other sources, may contradict constraints, and the global schema typically contains integrity constraints. Since the ability of a data integration system to respond to queries in terms of the global schema is one of its primary objectives, and because the response to a query is based on the data stored in the sources, inconsistency has a substantial impact on the system's capacity to respond in a meaningful way.

The global schema frequently includes integrity requirements, and sources may contain data that violates integrity constraints when combined with data from other sources. Since responding to inquiries in terms of the global schema is one of the primary goals

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of a data amalgamation system. How to model the consistency of the data and, consequently, specify and establish that the data is clean, is one of the most crucial concerns in relation to data cleaning (Angeles & MacKinnon, 2004). Data amalgamation has been grappling with the difficult task of resolving structural, syntactic, and semantic heterogeneities between source and target data for several years.

II. Review of Literature

Different departments within a large, contemporary company will very certainly create, store, and search for their vital data using various platforms. However, the company can only fully understand the value of the data they hold by merging the information from these diverse platforms. One method of integrating data is called database federation, in which a relational database management system is used as middleware to give users uniform access to a variety of disparate data sources. According to (Haas et al., 2002), they went through the fundamentals of database federation, introduce a few different types, and specify the circumstances in which each type of partnership should be employed.

Angeles & MacKinnon in 2004 contend that user quality priorities, data inconsistencies, and data quality differences among the participating sources have not been adequately addressed by the processes and optimization of information integration, such as query processing, query planning, and hierarchical structuring of user results. They suggested creating a data quality manager to manage semantic heterogeneity and data quality by establishing communication between the information integration process, the user, and the application. To specify the quality standards, metrics, and evaluation procedures, data quality manager will include a reference model, a measurement model, and an Assessment Model. By taking into consideration, data quality estimates to discover the ideal combinations for the execution plan, data quality manager will also aid in query planning. Data quality may also be utilized to resolve data inconsistency after query execution and inconsistent data detection. This method will result in the integration and rating of query results using the user-defined quality criteria. (Angeles & MacKinnon, 2004).

In this paper, we provide our initial set of findings on lowering uncertainty during data integration. We contend that certain guidelines must be followed when handling uncertainty at each of three different levels by data integration systems. First, because there may be too many of them to create and maintain or because the proper mappings might not be clear in certain fields, the mappings between the data sources and the mediated schema may only be generally correct (such as bioinformatics). Second, if information extraction methods are utilized to get the data from the sources, inaccurate data could be generated. Third, inquiries may be sent to the system using keywords rather than needing to follow a prescribed syntax.

a) Data Quality

Any inconsistent data and integration of data into systems would not be complete without hitting on how quality the data is. This could be the first challenge to affect the consistency of the data. Any challenge along one or more quality dimensions that renders data totally or partially inappropriate for use is what we refer to as a “data quality problem” (Strong et al., 1997). The term "high data quality" refers to data that is appropriate for use by data consumers and is handled regardless of the environment in which it is created and consumed. (Angeles & MacKinnon, 2004). According to (Angeles & MacKinnon, 2004). Accuracy, completeness, consistency, and timeliness are some examples of quality criteria or dimensions that have been used to define data quality.

b) Data Integration

Applications that need querying across several independent and heterogeneous data sources encounter a common difficulty called data integration. Progress in large-scale scientific projects where numerous researchers independently create data sets, improved collaboration between agencies from the government having a high-quality search and their sources of data across multiple sources on the internet all depend on how their data has been amalgamated. (Ioannou & Staworko, 2013)

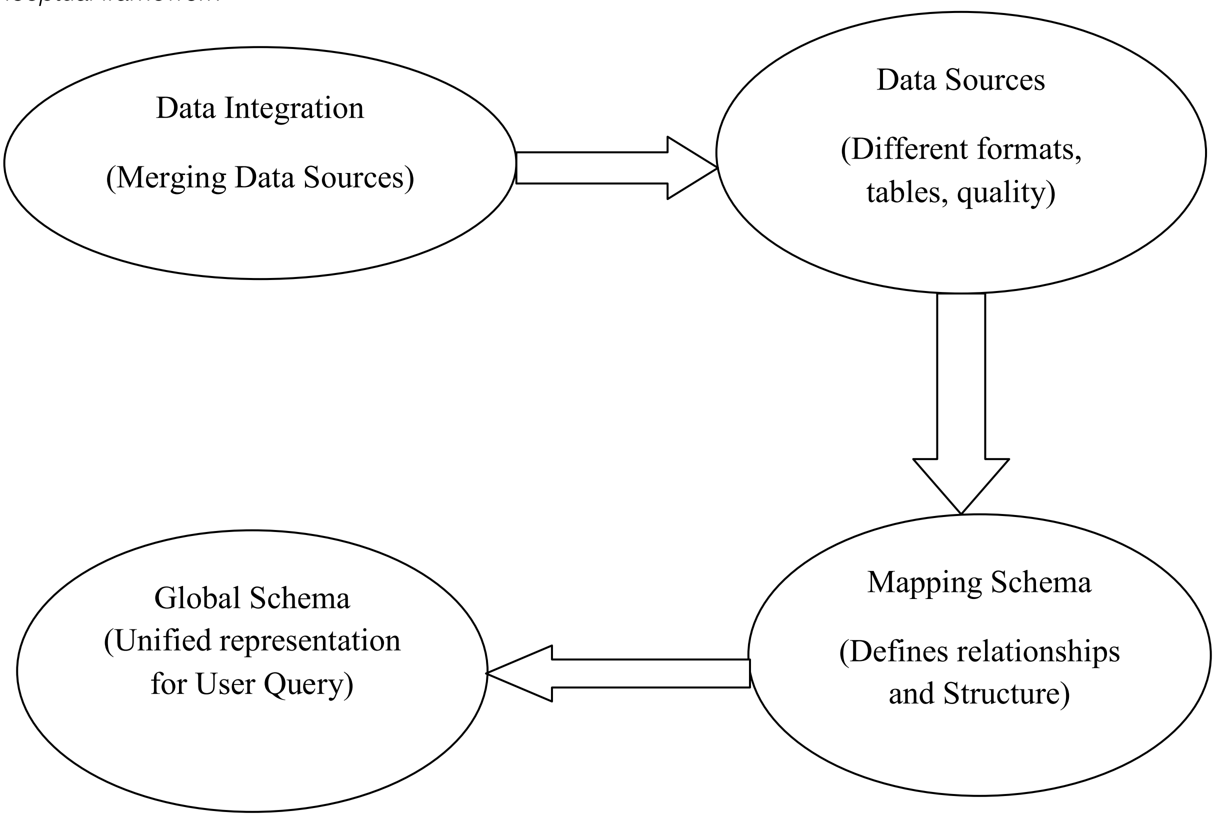
Amalgamation of data could also be seen from diverse angles, however it cannot be said without considering the volume thus, not only may each data source have a substantial amount of data, but there are now tens of thousands of data sources, even for a single field. (Sena et al., n.d.)Also said Velocity, thus, many of the data sources are particularly dynamic because of the rate at which data is being collected and regularly made available. For instance, there are several data sources that offer close to real-time, constantly updating data on the stock market, such as bid and ask prices, number of shares traded, etc. Traditional data amalgamation techniques are unable to provide an integrated view of stock market data from all these data sources. Veracity, thus, there are substantial disparities in the coverage, quality, and timeliness of the data given by different data sources (even within the same topic).Variety, thus, when it comes to how data is formatted at the schema level and how they represent the same real-world object at the instance level, data sources (even within the same domain) are incredibly diverse(Debattista et al., 2015). They show a great deal of variation even for quite comparable entities.

Uncertain mappings in the schema; Data amalgamation solutions employ schema mappings to specify the semantic relationships between the text in the mediated schema and the data in the sources. Schema mappings, however, may not be trustworthy. Accurate mappings between different data sources in applications are frequently challenging to create and maintain (Dong et al., 2009).

c) *Inconsistencies between data integration and data sources*

In fact, if the data obtained from the sources in a data integration system does not meet the integrity criteria, then there is no global database and query response is useless. When two sources' data contradict one other, this scenario results. This scenario is often handled by applying the proper transformation and cleaning techniques to the data that the sources have acquired(Coelho et al., 2010) (Bouzeghoub, M., & Lenzerini, M. (2001). This paper approaches the issue from a more theoretical standpoint in this section.

Conceptual framework



III. Methodology

In this method, data amalgamation is going to be based on the global schema. We speak about data amalgamation systems, whose goal is to combine data from many sources and give the user a single picture of that data. A representation of this unified view is provided by the global schema, which also provides a reconciled view of all data in a user-query form. It goes without saying that connecting the data sources to the global schema is one of the most crucial aspects of creating a data integration system(Pham et al., 2014). This mapping needs to be appropriately considered when formalizing a data integration system. However, in data amalgamation systems, there are components which are supposed to be used, thus the sources, the mapping, and the global schema itself. Mapping heterogeneous data sources to a unified global schema is one of the most critical aspects of data integration, yet also one of the most complex. The global schema provides an abstracted, integrated view of the sources, enabling users to query across sources as if they were a single repository. However, creating accurate mappings between sources and the global schema poses many challenges; sources often contain overlapping, redundant, or conflicting data representations. For example, two sources may have different definitions or formats for a customer entity. Resolving these discrepancies requires in-depth analysis of the source schemas and data.

Sources are dynamic, changing over time as new data arrives. Keeping mappings synchronized requires ongoing governance. Outdated mappings will propagate errors during integration according to (Y. Chen et al., 2020).

Sources may contain bugs, errors, inconsistencies, or missing values that get propagated

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through mappings. Cleansing and transforming source data is usually required.

The global schema offers a cohesive, acquiescent, and simulated representation of the primary sources, whereas the source schema naturally displays the structure of the sources where the real data are situated. The mapping's presumptions show how the components of the global and source schemas relate to one another. The global schema and source schemas serve different purposes in data integration system architecture. The global schema provides a consolidated, integrated view that abstracts the complexity of the sources. It creates a single logical interface that users can query to access data from multiple sources. The global schema structures the data into the forms and relationships needed to support business reporting and analysis. It is optimized for flexibility, performance, and ease of use.

In contrast, source schemas directly reflect the underlying structure and semantics of the original data sources. They model the physical storage, formats, and data elements within each source. Source schemas preserve the quirks and nuances of how each system represents data. They may contain duplicative or overlapping data elements. Source schemas favor accuracy and completeness oversimplification.

These differing purposes lead to key distinctions which are.

Global Schema: Unified view spanning sources, simplified data model, unified semantics, optimized for querying and analysis.

Source schema: System-specific view, matches source storage structure, preserves source peculiarities, optimized for accuracy.

On the other hand, the local as view approach is based on the idea that each source's content should be described from a modeling perspective in terms of a view over the entire schema. At the point when the information incorporation framework is established on a model or a metaphysics, this kind of circumstance is critical (Gruninger, M. 2002). When the data integration system is built on a global schema that is dependable and well-known within the company, this idea works best.

IV. Discussions and Findings

Due to the possibility of interdependence in the data supplied by the Analyzed Database, consistency may not have been attained. However, it is impossible to collect all the data while avoiding null values, this issue has persisted. Accuracy, reliability, availability, timeliness, and other data restrictions specific to each autonomous component database are also addressed. There are several methods that have been used to resolve data base inconsistencies. (Angeles & Mac Kinnon, 2004). The presence of null values in source data can undermine the accuracy and reliability of integrated data sets. Null values typically indicate missing data - facts that should exist but were not captured or stored by the source system. This absence of data leads to incomplete snapshots of business entities, lacking critical attributes needed for analysis. Null values also reduce confidence in the correctness of integrated data. A missing value provides no actual evidence that can be checked or validated. Questions arise over why data is missing and whether the absence itself implies inaccurate representations.(Dong et al., 2009) also says during integration, nulls can introduce ambiguities when linking records across sources. If a key attribute is null, determining matches across sources becomes far more difficult. Nulls also complicate joins and data aggregation. Once integrated, large volumes of nulls make quality assurance and issue diagnosis challenging. Pinpointing the root causes of data gaps requires tracing nulls back to the upstream sources and transformation logic. For certain types of analysis, such as mathematical calculations or machine learning, nulls must be imputed or substituted for proxy values (Agomor & Agomor, 2023). This can introduce estimation errors if not done carefully.

V. Conclusion

In data integration, it may not be possible to reconcile the data collected from the sources with the mapping and limitations of the global schema in a way that's acceptable to both, as defined earlier. For example, this happens when the tuples returned by the view related with connections break a key imperative to the given connection for a worldwide pattern, as the presumption of sound perspectives does not let us to tuples with duplicate keys should be ignored (Lenzerini, 2014). We need a different description of the mapping if we are not to conclude that there is no global database that is appropriate in this context. We specifically need a categorization that allows query processing even when the sources' data is corrupt. does not adhere to the global schema's integrity constraints. Challenges arise from inconsistencies, redundant data, and constraints imposed by the global schema. Organizations must reconcile schema limitations, integrity constraints, and defective source data that violates business rules. Thoughtful planning, extensive validation, iterative enhancements, and continuous data monitoring are imperative for flexible, scalable data integration with minimal disruption. Further innovations in machine learning, automation, and data provenance tracing will aid future integration initiatives.

VI. Recommendations

In light of our findings, we recommend implementing a comprehensive data quality framework

Standardizing data formats, leveraging ETL tools to transform and validate data, defining business rules and integrity checks, implementing master data management, profiling integrated data, automating standardization and cleansing, establishing data governance practices, treating integration as an iterative process, and continually monitoring and enhancing the process based on identified issues are critical ways to address inconsistent data in integration. An iterative approach that focuses on upfront planning, leverage machine learning for pattern recognition and identification of anomalies, validation throughout the pipeline, governance, and continuous improvement will allow organizations to effectively tackle data inconsistencies.

VII. Future Works

In future research, we envision the development of an advanced data quality framework that incorporates machine learning and natural language processing to automatically detect and rectify real-time data quality issues, alongside the exploration of semantic data integration methods for improved alignment of diverse data sources, including unstructured data. To streamline data integration, user-friendly interfaces for mapping management will be created, while robust data governance practices and compliance considerations will be integrated throughout the process. We will also focus on optimizing scalability and performance for large-scale datasets and examine the integration of data residing in cloud environments, emphasizing standardized protocols and exploring the inclusion of machine learning models directly into the data integration process to enhance accuracy and efficiency.

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How Trust Influences the Emergence of Collective Intelligence? A Group Dynamic Perspective

By Deqiang Hu, Yanzhong Dang & Xin Yue
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Abstract- Collective intelligence (CI) is critical for groups to solve a variety of problems. Such emergent property of the group as a whole is the result of group interaction processes that may inevitably lead to different cognition, collaboration and relationship between individuals, even conflict within group. A key question concerning problem solving is whether and how conflict influences the emergency of collective intelligence. Here, we used trust and distrust to indicate harmony and conflict state of the group. We utilized agent-based modeling to examine the emergent outcomes resulting from trust-based group interaction. Our results support the conclusion that CI emerges in moderate task complexity conditions. We further showed that the maximum level of CI is predicted by distrust. We also found that trust-based positive and negative feedback mechanism worked simultaneously in group problem solving process.

Keywords: collective intelligence, complex adaptive systems, agent-based modeling, trust model, conflict.

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How Trust Influences the Emergence of Collective Intelligence? A Group Dynamic Perspective

Deqiang Hu [α], Yanzhong Dang [σ] & Xin Yue [ρ]

Abstract- Collective intelligence (CI) is critical for groups to solve a variety of problems. Such emergent property of the group as a whole is the result of group interaction processes that may inevitably lead to different cognition, collaboration and relationship between individuals, even conflict within group. A key question concerning problem solving is whether and how conflict influences the emergency of collective intelligence. Here, we used trust and distrust to indicate harmony and conflict state of the group. We utilized agent-based modeling to examine the emergent outcomes resulting from trust-based group interaction. Our results support the conclusion that CI emerges in moderate task complexity conditions. We further showed that the maximum level of CI is predicted by distrust. We also found that trust-based positive and negative feedback mechanism worked simultaneously in group problem solving process. And these two mechanisms played the role of "valve" controlling knowledge flow and "bridge" connecting individuals respectively, which can better explain how trust influences the emergence of CI. Finally, we found that appropriate conflict is beneficial to collective intelligence.

Keywords: collective intelligence, complex adaptive systems, agent-based modeling, trust model, conflict.

I. Introduction

People tend to form groups when they have to solve difficult problems because groups seem to have better problem-solving capabilities than individuals (1). When group members interact with each other and combining knowledge across individuals, the group, as a whole, results in the acquisition of the ability to solve new or more complex problems (2). This kind of ability is called collective intelligence (CI), which is the general ability of a particular group to perform well across a wide range of different tasks (3).

Collective intelligence has been used as a determining factor to problem solving (1), collective performance (3), knowledge management (4), group synergy (5) and has also been a measure of the advantage of being in a group compared to isolated individuals, -aka "nominal group" (5). Though CI does emerge in human groups, crowds, of course, are not always wiser than individuals (6). Previous studies have shown that it is not a matter of putting a group of smart people together that makes an effective team and emergent CI, but rather requires cooperation and coordination among members (7). Differences in perspective are created on determinants of CI (8), such as who is in the group (composition), e.g, diversity (9) and the proportion of females in the group (3); what they face (situation), e.g, task complexity (5) or task difficulty (1); and how they share information (process), e.g, intermittent breaks in interaction (10).

However, to the best of our knowledge, previous studies have only addressed one or two of these perspectives (composition, situation, process), and few works examined them from a holistic perspective. One of the reasons may be the fact that CI involves simultaneously individual processes, group dynamics, and organizational or institutional contingencies (11). Though the researchers have made great contributions to the study of the relationship between IQ and CI, they made hypothesis of perfect communication in group interaction, which is an idealized description of the information share process (1). In other words, it is assumed that the team is always in a harmonious atmosphere, but this is difficult to achieve in reality. CI, as interrelated team property, is emergent state 39 and is dynamic in nature resulting from coordination and competition among the team members (12). The group interaction is inherently an uncertain and complex process, which makes it difficult for teams to maintain harmony all the time. Different behavior, opinion formation, and decision making (13) will inevitably arise between members, and it may easily leads to discord, even to the point of conflict. Existing studies found that conflict contribute significantly to organization productivity (14), they argued that conflict can be constructive and beneficial (15). While the other researchers advocated that conflict is bad, harmful and was labeled as a destructive force (16, 17). Most of the past research focuses only on static levels of conflict, ignoring that conflict might occur over time (18).

As trust is considered the antecedent of conflict (19, 20), we use trust (positive trust, PT) to represent harmony state and distrust (negative trust, NT) to represent the conflict state in teams (21, 22). We investigate the influence of conflict on the emergence of CI by further exploring how trust generates, changes, or even comes to be dissolved during group interaction. As such, based on complex adaptive system (CAS) theory (23, 24), our focus takes integration of composition, situation and process perspective and we see groups as complex, adaptive, dynamic systems(25). We build

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upon the rich tradition of agent-based modeling and focus on emergent consequences of agent's trust-based communication for problem solving. Agent-based models are especially helpful and appropriate to investigate this because, as "computational experiments," they (1) produce empirically testable hypotheses in a variety of contexts (e.g., large or small-group experiments, etc.); and (2) enable us to quickly and effectively test for causality across varying forms of structure (e.g., harmony and conflict state) and agency (e.g., agents with different knowledge). They can also inductively investigate the non-linear and synergistic effects of small changes in agent behavior on the entire system (9).

We use the term knowledge work team (26, 27) to refer to small groups of individuals working outside of traditional hierarchical lines of authority on a temporary basis on the types of knowledge-based tasks (28). The purpose of this paper is to examine the role of conflict on the emergence of CI in such teams. We develop a model which links task commitment and trust to conflict and ultimately to CI. Next, we briefly introduce the study design and results for revealing the mechanism of how trust works in group interaction (trust-based communication), and based on which to explain why some groups are more collectively intelligent than others (more details see SI Appendix S4 and S5).

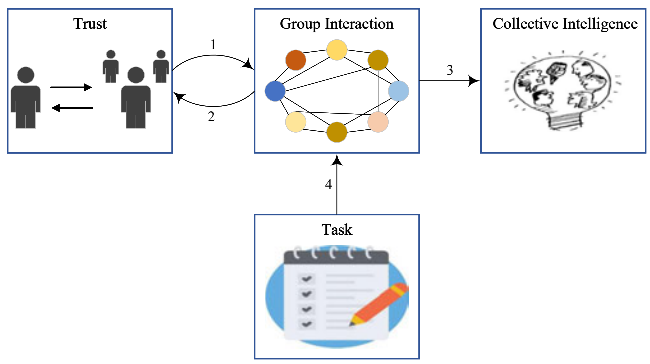

Fig. 1: Framework trust Influences Collective Intelligence through Group Interaction Across Different Task Difficulty. and Trust Also Generates and Varies in Group Interaction. Two Progressive Computational Experiments were Conducted. Experiment 1 Follows the Route 1+3+4 and Experiment 2 Follows the Route 1+2+3+4

II. Study Design

It has been demonstrated that collective intelligence emerges through group interaction. In knowledge work team context, this process involves interpersonal interaction such as knowledge transfer, exchange and share among members and is moderated by the task difficulty (route 3+4 in Fig.1). As mentioned above, existing agent-based experiment on the emergence of CI was conducted in assumption of "perfect communication". However, studies in sociology, psychology and social psychology have shown that group interaction processes such as cooperation, knowledge exchange, are closely related to trust (29-31), and that differences in trust evolution lead to differences in the effectiveness of knowledge exchange (30). Thus, this paper introduces trust into the group interaction process and argues that the interpersonal interaction between members is based on "trust-based communication". Trust plays a significant role in transferring knowledge during the group interaction process (relationship 1 in Fig.1). Moreover, trust is also an important product of the interaction and evolves as it proceeds (relationship 2 in Fig.1). The interaction between psychology and behavior makes the whole process complex and uncertain. Therefore, two progressive computational experiments were designed to investigate how the function of trust influences CI through group interaction (route 1+3+4 in Fig.1) and further investigate how the combination of trust's generation and function influences CI (route 1+2+3+4 in Fig.1).

We designed the experiment based on Carletti's work (1), adding an important factor-trust. We detailed the interaction process through trust-based communication instead of perfect communication. The new challenge is that trust generates in the group interaction process and in turn influences knowledge transfer when members communicate with each other. We de-scribe this process with trust-based group interaction as shown in supplementary materials (SI Appendix, S1.5). Previous studies have revealed that, in interacting groups, task complexity moderates CI generation (1, 5). Thus, we aim to examine not only if, but also how trust influence the emergence of CI across different task complexity (or task difficulty). Towards this end, two progressive computational experiments were conducted. Experiment 1 investigates whether trust have an impact on the formation of collective intelligence. Experiment 2 investigates whether and how the combination of trust's generation and function influences the emergence of CI. Both experiments are conducted under various settings (team scale M, task difficulty τ, knowledge dimension D, tent knowledge distribution parameter β, and team knowledge range, see Appendix S3).

III. Results

Results of Experiment 1: Fig. 2 shows the results obtained using "trust-based communication". And the results indicated that different levels of trust do have an impact on the formation of collective intelligence. As shown in the left panel of Fig. 2, the curve reflects the variation of collective intelligence across different task difficulties at IT = 1, which corresponds to the "perfect communication" in Carletti's study (1). Our results support their findings. Further, the results of varying the different trust levels are shown in the right panel of Fig. 2. The significant difference between the curves indicated that different levels of trust had different impact on the results and suggest that trust does affect the formation of CI. It is also found that the shape of each curve has a high similarity, i.e., each curve shows a "bell-like shape" across different trust levels. So we argue that there may exist a regularity in the influence of trust on the formation of CI. Furthermore, we can also find that when the team formed collective intelligence, the maximum CI tends to increase with the boosting of trust level, which indicates that the dynamic change process of trust may affect the formation of CI. So the following experiment results will interpret the effect of trust dynamic on the emergence of CI.

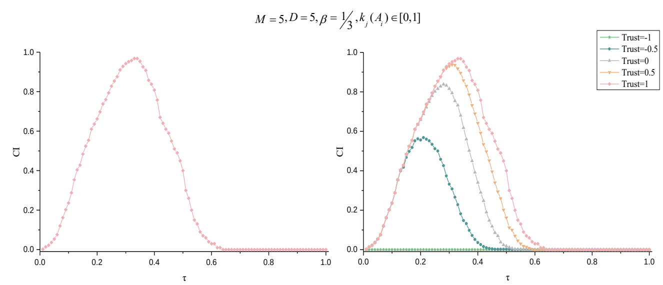

Fig. 2: Function of trust and collective intelligence (CI). Both panels show the relation- ship between trust and CI across different task difficulties. In the left panel, each trust between two members is fixed at 1 which corresponding to the perfect communication (1). In the right panel, each trust between two members is fixed at -1, -0.5, 0, 0.5, 1 respectively which corresponding to the trust-based communication. The results generated in the experimental settings of team scale M = 5, task difficulty τ [0, 1], knowledge dimension D = 5, tent knowledge distribution parameter β = 1, and team knowledge range indicating that any agent *i*' any *j* type of knowledge *kj* (*Ai*) is in [0, 1]. See SI Appendix, section S3, for details and SI Appendix, Figs. S5-S7, for more results under various settings

Results of Experiment 2: As shown in panel 1 of Fig. 3, with the increasing of task difficulty (τ), the collective intelligence (CI) first remained constant at 0, then increased and then decreased, and finally remained constant again at 0. The overall pattern of the CI was "bell-like shaped", which was extremely similar to the shape of the CI got in Experiment 1. It was also found that as the task difficulty increased, trust first remained constant at 0, then increased and then decreased to 0, then decreased further, and finally remained constant at around -1. The overall pattern shows an "inverse S-shape". We can also find that CI did not reach the maximum when the trust was maximum, while when the CI was maximum, the team corresponded to a certain degree of negative trust. To explore the intrinsic influence characteristics, trust was further analyzed by statistically separating positive trust (PT) and negative trust (NT).

As can be seen in panel 2 of Fig. 3, when the CI is maximum, not all members' trust is negative, while positive and negative trust coexist. This coexistence indicates that some members' expectations are met while others' are not. So we can infer that the trust formation process among individuals are different, which leads to the formation of trust in team level a complex and multi-level process. Therefore, the influence of trust on CI is also complex and is an emergent relationship. In order to reveal this emergent relationship, further analysis of its intrinsic mechanism is needed.

As shown in panel 3 of Fig. 3, with the increasing of task difficulty, collective satisfaction first remains constant at a value of 0, gradually increases to maximum, then decreases, finally remains constant again and approaches a value of 0. The trend of collective satisfaction is very similar to that of positive trust (PT). The satisfaction degree of individual expectation drives changes in dyadic trust between individuals, so, at the overall team level, collective satisfaction (CS) also affect interpersonal trust. However, between the zone of two dashed lines, both CS and trust keep decreasing with increasing task difficulty, but CI still keeps increasing. A counterintuitive phenomenon emerged, and further analysis is needed to better explain this phenomenon. Thus we take interaction rate (IR) and knowledge flow (KF) into account additionally. IR indicates the percentage members participating in the interaction and KF indicates the amount of knowledge transferred during the interaction.

As show in panel 4 of Fig. 3, further exploration of the IR and the KF revealed that the relationship between the influence of trust on collective intelligence can be divided into six phases.

1. During the a-b phase, trust had no significant effect on CI. As the task difficulty increased, both CI and trust remained constant and maintained at the value of 0. The task in this phase is extremely simple, and members can complete it by their own knowledge alone. So all members had no knowledge need and thus did not develop motivation or behavior to acquire knowledge. The team existed no interpersonal interaction, so either interaction rate (IR) or the knowledge flow (KF) is 0. The absence of interpersonal interaction means that no expectations are formed, so trust did not generate between members, thus the trust is 0. At the same time, no satisfaction with expectations is formed, so the collective satisfaction (CS) is also 0. Since the members did not need to exchange knowledge through interpersonal interaction and could complete the task independently, no collective intelligence emerged and the CI is 0.
2. During the b-c phase, the increase of trust promotes CI. As the task difficulty increased, some part of members could not complete the task by their own knowledge alone. So they expected to obtain knowledge from other teammates and generated knowledge need. The knowledge need further transformed into the motivation of seeking knowledge and generating interpersonal interaction behavior. The success of knowledge transfer leads to the satisfaction of members' knowledge need, so CS keeps increasing and knowledge flow (KF) keeps improving. At this time, the expectations of members can also be rewarded and satisfied, which promotes the generation of positive trust among individuals and makes trust improve continuously. In turn, the improvement of trust promotes the increase of KF, which further ensures that more knowledge needs can be satisfied. Thus, collective satisfaction and trust promote each other, and both of them show an increasing trend. It is also the mutual promotion of the two that leads to the smooth knowledge transfer, which makes more members participate in the interaction and bring into play the advantage of the overall complementary knowledge of the team, thus promoting the emergence of CI.
3. During the c-d phase, the CI was gradually increasing despite the decreasing trust. As the task difficulty increased, the knowledge acquired by some members does not reach the expected level, making the trust decrease. However, CS is increasing, indicating that the knowledge needs of most members were still met. At the same time, the increase in IR and KF indicates that knowledge can flow effectively among members, and members keep learning and digesting the acquired knowledge, further transforming it into their own ability. Thus they can complete tasks that they could not solve before, reflecting the advantage that the team can keep learning, so the CI is improving.
4. During the d-e phase, trust continues to decrease while CI is still increasing. With the further increase of task difficulty, more and more members could not complete the assigned tasks. So they need more knowledge, while the fact turned out contrary to their desire, which made CS further decrease. The decrease of CS caused the expectation not to be met, which lead trust to decrease or even turn negative. However, in this case, the generation of negative trust stimulated the need of members to acquire knowledge from others and enhanced their motivation to seek knowledge. This stimulation in turn increases IR and enables knowledge to flow among members more effectively, so that the KF keeps increasing. Thus, the active participation of all team members is mobilized, and the wisdom of all members is gathered, thus promoting the continuous improvement of CI. From this perspective, the stimulation of appropriate negative trust is beneficial to the emergence of CI. 0
5. During the e-f phase, the reduction of trust inhibited CI. The knowledge needs of most members could not be met due to the further increase in task difficulty, leading to a rapid decline in CS. A large amount of negative trust was generated among members, leading to a rapid decrease in trust, which severely hindered interpersonal interactions among members. Though the whole team was already involved in the interaction process (IR=1) and was able to transfer knowledge flow (KF>0), it was still unable to complete the task, causing the team to continuously disintegrate and resulting in a decreasing CI.
6. During the f-g phase, trust has no significant effect on CI. As the task difficulty reached hardest, both trust and CI kept constant, with trust remaining around -1, CI remaining around 0, and CS also remaining around 0. The task at this phase is extremely difficult, and the knowledge required for the task is much greater than the knowledge level of the members. No matter how all members fully interact with each other, the task cannot be completed. Neither the knowledge needs nor the respective expectations of members could be met, which makes the members distrust each other. Both trust and KF reached minimum levels. At this time,

the task cannot be completed regardless of whether a team is formed, so the CI is 0.

From an overall perspective, though CI is 0 in both a-b and f-g phase, the inner mechanism that produces this phenomenon is different. This difference can be explained through the variation process of trust. The trust of the former is 0, indicating that the task can be completed without interpersonal interaction, which is why CI does not emerge. While the trust of the latter is -1, indicating that the task cannot be completed even with sufficient interaction, which is why CI does not emerge. (See SI Appendix S4 for the relationship between CI and trust in different settings)

From panel 4 of Fig. 3, we can also see that the formation and changes of CS, trust and CI are not synchronized. Firstly, the changes of CS affected how trust varied, and the changes of trust in turn affected CS, and the two will interact with each other and eventually affect CI. It is not difficult to find that when trust is maximum, CI does not reach the maximum; and when CI reaches the maximum, trust is negative. Examination of our definition of trust indicates that there is a certain level of trust conflict in the team when CI reaches the maximum. But it is not as long as there is conflict that the team can emerge collective intelligence. For example, at the c-f phase in panel 4 of Fig.3, trust keeps decreasing in negative level, indicating that the team is in a state of conflict, but CI didn't emerge. It suggests that only appropriate trust conflict can promote the emergence of CI. At the intersection point of E line and trust in panel 4 of Fig. 3, the CI reaches the maximum, and the trust level at this intersection point can be called "Best Trust Conflict" (BTC).

$$M = 10, D = 20, \beta = 2/3, k_j(A_i) \in [0.2, 0.8]$$

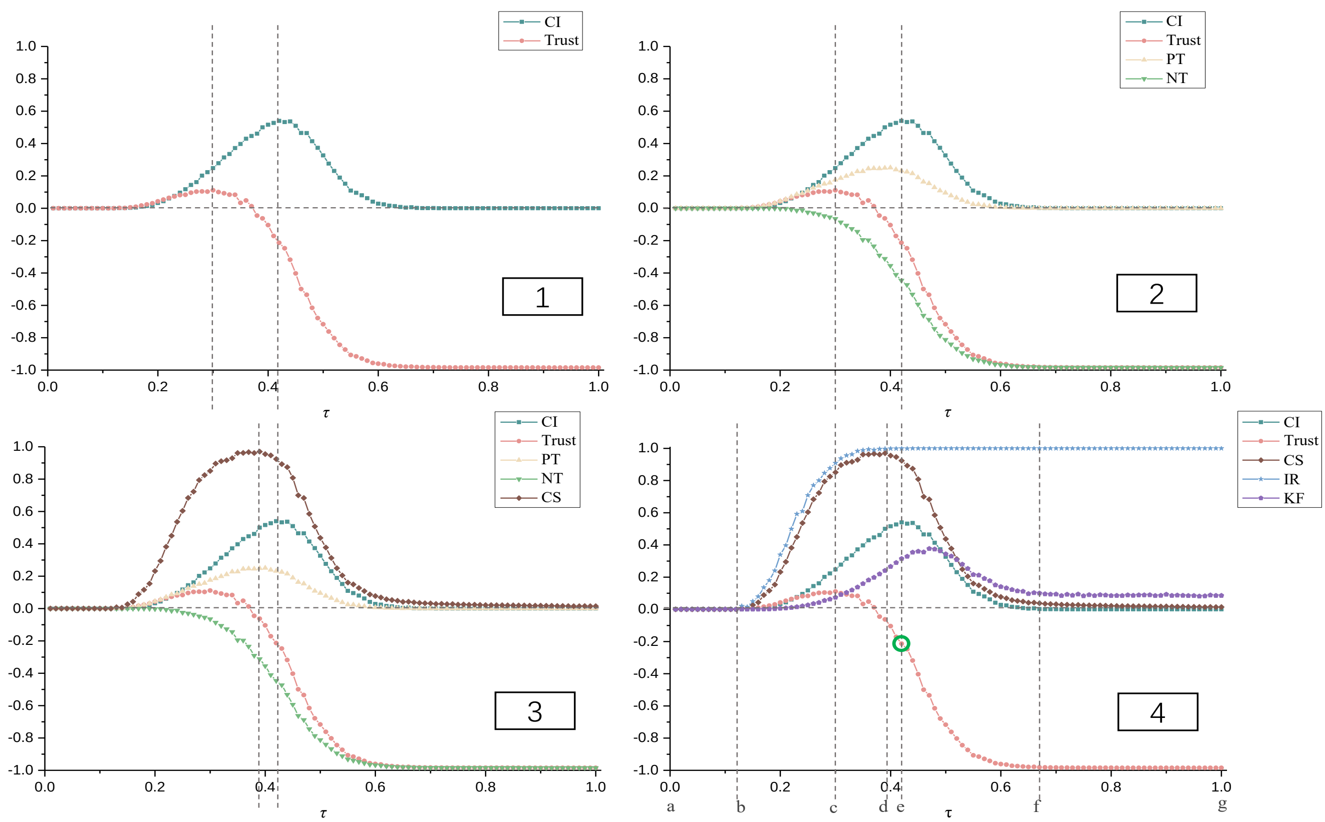

Fig. 3. Combination of trust's generation and function and collective outcomes. Panel 1 shows the variation of trust and collective intelligence (CI) across different task difficulties. Panel 2 adds the variation of positive trust (PT) and negative trust (NT) additionally compared with panel 1. Panel 3 adds the variation of collective satisfaction (CS) additionally compared with panel 2. In panel 4, PT and NT are replaced with interaction rate (IR) and knowledge flow (KF) compared with panel 3. The results generated in the experimental settings of team scale $M = 10$, task difficulty τ [0, 1], knowledge dimension $D = 10$, tent knowledge distribution parameter $\beta = 2$, and team knowledge range indicating that any agent *i*' any *j* type of knowledge *kj* (*Ai*) is in [0.2, 0.8]. See SI Appendix, section S3, for details and SI Appendix, Figs. S8-S13 for more results under various settings

IV. Discussion

This study extends research on group problem solving and group conflict by exploring the mechanisms of collective intelligence emergence in teams, using the trust-based group interactions to advance this work. Thus, rather than simply emphasizing how knowledge, trust, and collective intelligence change, we focus on how the entire problem-solving process evolves based on group interaction, and how trust influences the emergence of collective intelligence during the knowledge transfer, thereby facilitating knowledge work teams to solve complex problems.

Trust has an impact on CI in two ways: on the one hand, trust affects knowledge transfer and thus CI; on the other hand, trust affects the number of people involved in communication and thus CI.

Stimulated by the task, team members produce knowledge needs, and then generate the motivation and behavior of seeking knowledge, finally prompting interpersonal interactions among members to acquire knowledge. Thus the knowledge is transferred between members and knowledge flow generates in the team. In knowledge transfer process, members form expectations and satisfaction with others based on the availability of knowledge flow, which in turn generates and modifies trust. Positive trust is formed when the acquired knowledge satisfies expectations, and the accumulation of positive trust promotes members to transfer more knowledge. The effective knowledge transfer increases knowledge flow, improves collective satisfaction, and further promotes trust generation, forming a positive feedback mechanism (Fig. 4 lower cycle). On the other hand, though the increase of trust is conducive to improving the knowledge transfer, it may form path dependence among members, which makes interpersonal interaction just limited to a few people and prevents more members from participating in group interaction. This path dependence diminished the proportion of participants in the team and reduced the opportunity to acquire knowledge, which hindered the knowledge flow and forms a negative feedback mechanism (Fig. 4 upper cycle).

As can be seen in Fig. 4, the two cycles generate two feed-back mechanisms in the team. The increasing task difficulty stimulates members to create more knowledge needs and drives the interpersonal interaction. If the expected knowledge needs of members can be satisfied, trust will increase. On the one hand, this increase in trust triggers positive feedback mechanism, which leads to increase in knowledge flow, satisfaction and trust. And on the other hand, negative feedback mechanism is triggered concurrently, which forms path dependence and leads to decrease in knowledge flow, satisfaction and trust. Conversely, if members' expected knowledge needs are not met, trust will decrease, and both positive and negative feedback mechanisms will be triggered. Thus, whether trust increases or decreases, both feedback mechanisms work simultaneously, resulting in further changes in trust, which in turn trigger new positive and negative feedback mechanisms. It is in these two cycles that harmony and conflict interact and various factors cause and effect each other, promoting the development of the team and making the CI emerge.

Trust explains the collective dynamics. Both positive and negative feedback mechanisms allow us to better understand how trust influences the emergence of collective intelligence. In the positive feedback mechanism, trust acts as a "valve" that controls the knowledge channels by influencing the amount of knowledge flowed, which in turn affects CI. In the negative feedback mechanism, trust acts as a "bridge" that connects each knowledge source by influencing the number of people involved in the group interaction, which in turn affects CI. Therefore, when most members have positive trust, their interactions are prone to path dependence and some members may always be absent to group interaction, which is not conducive to bringing out the maximum CI of the team. From this perspective, a certain degree of negative trust may stimulates the team to mobilize its vitality and finally improves the emergence of CI. However, when there is too much negative trust, it will seriously hinder the flow of knowledge, which is harmful to the emergence of CI. Our results are consistent with the view of conflict theory that appropriate conflict is beneficial to team performance and team development (18). Thus, there is a suitable ratio of positive and negative trust to form the "best trust conflict", so that the CI can emerge the maximum in team.

Our study findings are as follows- (1) Trust has an impact on the emergence of collective intelligence in knowledge work teams. This impact is non-linear, and the two show a symbiotic evolutionary relationship. (2) This symbiotic evolution is moderated by task difficulty. Only when the team undertakes an appropriately difficult task, trust has a significant effect on collective intelligence and a highest level of collective intelligence emerges. (3) The highest level of collective intelligence does not emerge when the level of trust is highest, but when the collective intelligence peaks, the team corresponds to a certain degree of negative trust, indicating that appropriate trust conflict is conducive to the emergence of collective intelligence. However, excessive trust conflict leads to team dissolution, which is harmful to the emergence of collective intelligence. (4) The inner mechanism of trust's influence on collective intelligence is revealed through positive and negative feedback cycles.

It has been shown that in different periods of team development, the degree of attention to team “results” and “processes” should be different, with more attention to results in the early stages and more attention to processes in the later stages (32). In this paper, the above phenomenon can be explained from the perspective of how trust influences the emergence of collective intelligence. In the early stage of the team, the task is relatively simple and the task can be solved without group interaction. So the management strategy of the team should be result-oriented so as to improve the performance of the team. While in the late stage of the team, especially the knowledge work team, it often deals with some extremely complex tasks. At this time, the team atmosphere is very tense due to the pressure of undeliverable tasks, and the interpersonal trust relationship between members becomes very fragile and generates a great deal of distrust, which makes the trust relationship break down rapidly. Team will disintegrate due to the trust problem if the “results” are pursued persistently. In this situation, if the team can pay more attention to the “process”, especially the interpersonal interaction process between members (33), and then improve the trust between members through appropriate management strategies (34), it will help the team to solve the task, improve performance, and even promote the emergence of the collective intelligence.

In addition, the conclusions reached in this study echo the existing research work related to task difficulty, collective intelligence, and problem solving (5). The findings suggest that, on the one hand, when solving generally complex problems, teams are able to distribute work, share information, and correct errors, thereby facilitating problem solving. On the other hand, when tasks become more complex, teams may lead to idleness, slackness, and interpersonal conflict, which can be detrimental to problem solving. From the perspective of trust-based group interaction, when the team solves the general complex problems, knowledge transfer can be smoothly carried out among members (sometimes the task can be completed with-out communication). Most members’ knowledge needs can be satisfied, thus the formation of trust is promoted, which in turn is conducive to the emergence of collective intelligence and ultimately contributes to problem solving. When the task becomes more complex, the knowledge needs of the members cannot be mutually satisfied. This dissatisfaction deteriorates the trust relationship and generates a lot of distrust among team members, leading to the conflict and disintegration in the team and finally hindering the emergence of collective intelligence that is detrimental to the completion of the task.

In summary, this paper investigates the emergence of collective intelligence through the conflict caused by trust. First, our ABM experiment reproduces the phenomenon that simple and difficult tasks are not conducive to the formation of collective intelligence, while appropriate task difficulty is conducive to the formation of collective intelligence. Furthermore, our study also provides a better explanation underlying this phenomenon through positive and negative feedback mechanisms based on trust, and provides a possible explanation for the contradictory findings of existing studies, e.g. the degree of attention to team “results” and “processes” and the different effect of task difficulty. We discuss how our findings can help create in which situations that trust can foster high CI. In addition, our method for capturing dynamic interaction of psychology and behavior paves the way for researchers to build testable causal theories of CI. Taken together, these findings suggest that the team process most critical for collective intelligence are those that can both control “valve” for smooth knowledge flow and build sufficient “bridge” for group interaction. In other words, trust-based positive and negative feedback mechanisms need to be well coordinated to address the appropriate level of conflict. And whether exists an optimal level of trust-based conflict for the emergence of collective intelligence is to be further explored in future studies.

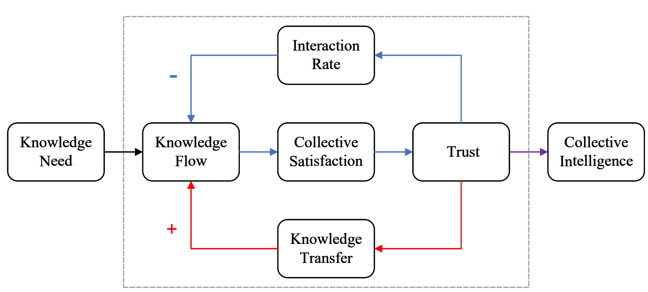

Fig. 4: Inner Mechanism between Trust and Collective Intelligence

V. Methods

This study involved two progressive computational experiments. We developed a representation of human behavior in computer simula-tions. The model was implemented as an agent-based simulation embodying stylized behaviors. We used Anylogic (Anylogic 6.9) to develop our codes for the

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ABM. In this way, we have a full control on the whole framework and we can adapt it at our will. The core of the ABM is using Anylogic agent-based modeling; such main module is the used by varying the several parameters to perform the numerical simulations presented in the work. A simulation is comprised up of M agents that completes after some number of rounds when all the tasks have been processed (whether solved or not). A simulation begins with a serious of tasks for agents to explore. Each agent is given some state of initial knowledge (e.g., tent distribution). If an agent can not solve the task alone, he/she will make an interaction with others and request for transferring knowledge. At the end of interaction, the agent will learn the knowledge transferred.

- *Team Modeling:* We regarded team as a complex adaptive system, the input is task across different complexity, output is collective intelligence, trust and interaction related results. The team's target is to solve the tasks. Team members are adaptive agents whose behavior is influenced by trust and who adjust their behavior according to the trust relationship and history interaction with other teammates.
- *Agent Behavior:* When an agent accepts tasks, he/she judges as to whether he can complete them. If he/she can, then he/she will finish the tasks and the whole process ends. Otherwise, he/she judges whether interaction object remains. If no one remains, he/she will abandon the tasks and the whole process ends. Otherwise, he/she will seek others for help and select an interaction object. Then he/she engages in the interpersonal interaction process. At the end of the interaction each agent had learnt the knowledge value on the topics under discussion from the teammates. The knowledge value learnt is based on the trust between teammates. After this interaction he/she reconsiders whether he/she can complete the tasks. If he/she still can't, then he/she will select another object for interpersonal interaction. Otherwise, he/she will finish the tasks and the whole process ends.
- *Trust Modeling:* As in small group, there will be frequent interpersonal interactions between agents. Thus, the trust between agents comes from the direct interaction. Our trust model is partly grounded on the direct trust of Das' Secured Trust model (35) and contains four processes: (1) formation of expectation, (2) generation of trust, (3) accumulation of trust, and (4) effect of trust. (SI Appendix S2)

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Optimal Control of Time-Delay Systems

By L. Keviczky, Cs. Bányász & R. Bars
Institute for Computer Science and Control, Hungary and Budapest University of Technology and Economics

Abstract- It is shown how the time delay of industrial processes can be handled in optimal control algorithms. Comparison of the classical and new modern algorithms is presented.

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GJCST-G Classification: *LCC: TJ213 ACM: G.1.7*

OPTIMALCONTROLOFTIMEDELAYSYSTEMS

Optimal Control of Time-Delay Systems

L. Keviczky [α], Cs. Bányász [σ] & R. Bars [ρ]

Abstract- It is shown how the time delay of industrial processes can be handled in optimal control algorithms. Comparison of the classical and new modern algorithms is presented.

Keywords: SMITH predictor, YOULA parameterization, time-delay.

I. Introduction

It is clear for control engineers that handling time delay requires special attention from the early days of the control history. The time delay is an uncancelable, invariant property of the process. The early goals tried to find design procedures which allow the selection of the regulator quasi independently from the delay. An early success story was the SMITH predictor or regulator [1].

Consider a continuous time delay process given by its transfer function

$$P(s)=P_+(s)\bar{P}_-(s)=P_+(s)e^{-sT_d}\,;\quad P=P_+\bar{P}_-=P_+e^{-sT_d} \qquad (1)$$

where T_d is the time delay, P_+ is stable and $P_-=e^{-sT_d}$ is the *Inverse-Unstable-Unrealizable* (*IUU*) part of the process, respectively. The original SMITH predictor is shown in Fig. 1, where r is the reference signal and y is the process output.

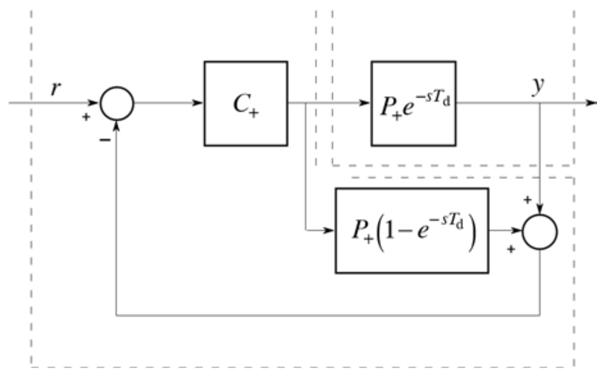

Fig.1: The Block-Scheme of the SMITH predictor

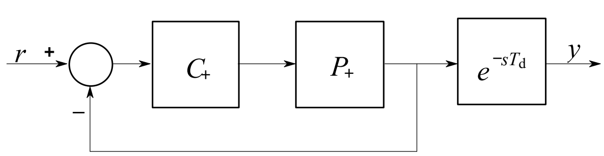

Fig. 2: Equivalent Block-Scheme of the SMITH predictor

It is easy to check that the SMITH predictor is equivalent to the scheme shown in Fig. 2. This figure clearly shows that the regulator C_+ can be designed to the delay free P_+, independently of the time delay T_d. This scheme explains why the SMITH predictor is also called SMITH regulator [8], [9], [10]. The whole procedure is, of course, not independent of T_d, because the predictor scheme contains block depending on the delay.

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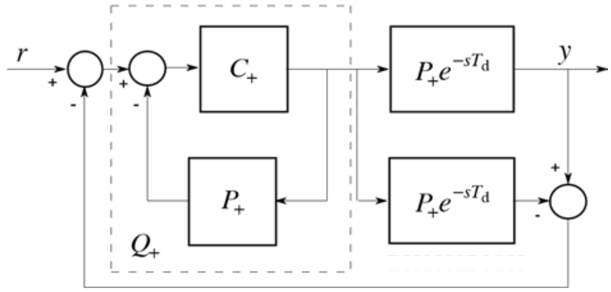

Fig. 3: *IMC* form of the SMITH predictor

It is possible to redraw the SMITH predictor into further schemes, which allow special interpretations. Fig. 3. shows another equivalent scheme what corresponds to the well known *Internal Model Control* (*IMC*) scheme and principle. Fig. 4. presents the resulting closed-loop with the serial regulator C_s equivalent to the application of the SMITH predictor.

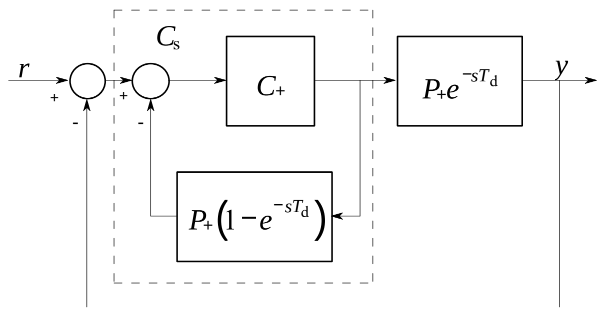

Fig. 4: The Resulting Closed-Loop of the SMITH predictor

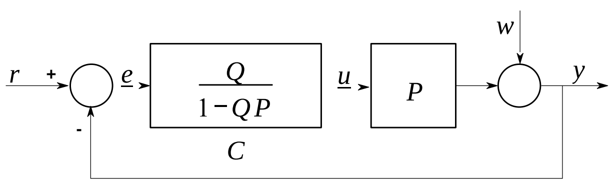

Fig. 5: YOULA-Parameterized Closed-Loop

II. The Youla Parameterization

A YOULA-parameterized (*YP*) closed-loop [4], [8] is shown in Fig. 5, where *e* is the error, *u* is the regulator output and *w* is the output disturbance signal, respectively.

Here the plant *P* is stable and the *All-RealizableStabilizing* (*ARS*) regulator is

$$C = \frac{Q}{1 - QP} \tag{2}$$

The closed-loop transfer function or *Complementary Sensitivity Function* (*CSF*)

$$T = \frac{CP}{1 + CP} = QP \tag{3}$$

which is linear in the stable YOULA parameter *Q*.

It is well known that the *YP* regulator corresponds to the classical *IMC* structure shown in Fig. 6, where *r* is the reference signal, *u* is the regulator output, *y* is the output signal and *w* is the output disturbance signal, respectively. If there is no disturbance and the internal model is equal to the process transfer function, the signal fed back to the reference signal is zero, and the forward path *QP* determines the reference signal tracking. The feedback loop rejects the effect of the disturbance and of the plant/model mismatch.

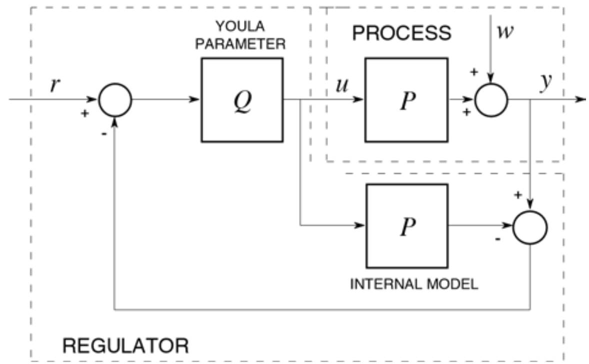

Fig. 6: *IMC* form of the *YP* Closed-Loop

It can also be well seen that Q_+ in Fig. 3 corresponds to the YOULA parameter. For a more detailed comparison consider the extension of *YP* regulator for more general case next.

III. A *G2DOF* Controller for Stable Linear Plants

The first systematic method introducing the *generic two degree of freedom* (*G2DOF*) scheme was presented in [5], [8], [9], [10] when the process is open-loop stable and it is allowed to cancel the stable process poles, which case occurs at many practical tasks. *2DOF* in this approach means that the dynamics of reference signal tracking and that of disturbance rejecting are different. This framework and topology is based on the *YP* providing *ARS* regulators for open-loop stable plants and capable to handle the plant time-delay, too.

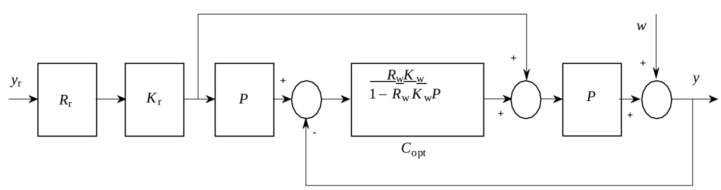

Fig. 7: The *generic 2DOF* (*G2DOF*) Control System

A *G2DOF* control system is shown in Fig. 7 for the stable process

$$P = P_+ \overline{P}_- = P_+ P_- e^{-sT_d} \qquad (4)$$

which is more general than what was used in (1), because here P_+ is stable and <u>I</u>nverse-<u>S</u>table-<u>R</u>ealizable (*ISR*), P_- is <u>I</u>nverse-<u>U</u>nstable-<u>U</u>nrealizable (*IUU*).

The optimal *ARS* regulator of the *G2DOF* scheme can be given by an explicit form

$$C_{opt} = \frac{R_w K_w}{1 - R_w K_w P} = \frac{Q_o}{1 - Q_o P} = \frac{R_w G_w P_+^{-1}}{1 - R_w G_w P_- e^{-sT_d}} \qquad (5)$$

where

$$Q_o = Q_w = R_w K_w = R_w G_w P_+^{-1} \qquad (6)$$

is the associated optimal *Y-parameter.* Furthermore

$$Q_r = R_r K_r = R_r G_r P_+^{-1} \;;\; K_w = G_w P_+^{-1} \;;\; K_r = G_r P_+^{-1} \qquad (7)$$

The *YP* regulator (5) can be considered the generalization of the TRUXAL-GUILLEMIN [2], [8], [9], [10] method for stable processes.

It is interesting to see how the transfer characteristics of the closed-loop look like:

$$y = R_r K_r P y_r + (1 - R_w K_w P) w = R_r G_r P_- e^{-sT_d} y_r + \left(1 - R_w G_w P_- e^{-sT_d}\right) w = y_t + y_d \qquad (8)$$

where y_t is the tracking (servo) and y_d is the regulating (or disturbance rejection) independent behaviors of the closed- loop response, respectively. So the delay e^{-sT_d} and P_- can not be eliminated, consequently the ideal design goals R_r and R_w are biased by $G_r P_-$ and $G_w P_-$. Here R_r and R_w are assumed stable and usually strictly proper transfer functions, that are partly capable to place desired poles in the tracking and the regulatory transfer functions, furthermore they are usually referred as reference signal and output disturbance predictors. They can even be called as reference models, so reasonably $R_r(\omega=0) = 1$ and $R_w(\omega=0) = 1$ are selected. The unity gain of R_w ensures integral action in the regulator, which is maintained if the applied optimization provides $G_w P_-(\omega=0) = 1$.

The role of R_r and R_w (predictors or filters) is threefold.

They prescribe the tracking and regulatory properties of the control loop. They influence the magnitude of the actuating signal and also influence the robustness properties of the control system.

An interesting result was found [6] that the optimization of the *G2DOF* scheme can be performed in H_2 and H_∞ norm spaces by the proper selection of the serial embedded filters G_r and G_w attenuating the influence of the invariant process factor P_-. Using H_2 norm a *Diophantine-equation* (*DE*) should be solved to optimize these filters. If the optimality requires a H_∞ norm, then the NEVANLINNA-PICK (*NP*) approximation is applied.

After some straightforward block manipulations the *G2DOF* control system can be transformed to another form shown in Fig. 8, which is the generalized version of the classical *IMC* scheme in Fig. 6.

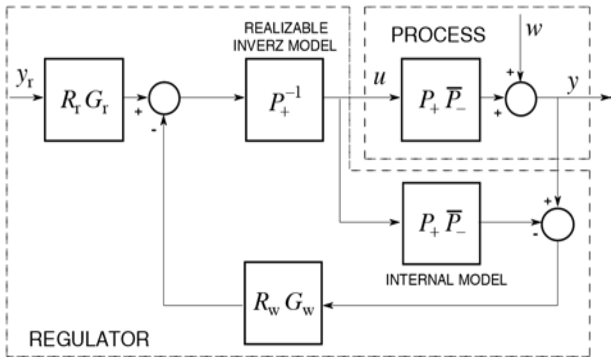

Fig. 8: The generalized *IMC* form of the *G2DOF* control system

IV. Smith Predictor as a Subclass of *G2DOF* Controllers

The previous two sections clearly show that the SMITH predictor is a special subclass of the *G2DOF* controllers with a *YP* parameterized regulator

$$Q_+ = \frac{C_+}{1+C_+P_+} = \frac{C_+P_+}{1+C_+P_+}P_+^{-1} = \frac{L_+}{1+L_+}P_+^{-1} = R_+P_+^{-1} \qquad (9)$$

if C_+ is stabilizing P_+, i.e., the delay free part of the process. Here the special *CSF*

$$T_+ = R_+ = \frac{L_+}{1+L_+} \qquad (10)$$

characterizing the closed-loop in Fig. 2 is the reference model R_+ and $L_+ = C_+P_+$ is its loop transfer function.

It is also easy to see that the resulting serial regulator of the SMITH predictor in Fig. 4 is

$$C_s = \frac{Q_+}{1-Q_+P_+e^{-sT_d}} = \frac{C_+}{1+C_+P_+\left(1-e^{-sT_d}\right)} = C_+K_S \qquad (11)$$

This formula presents the possible way of realization for a continuous-time (CT) case. Here K_S denotes a serial factor modifying the original C_+ regulator of the SMITH predictor

$$K_S = \frac{1}{1+C_+P_+\left(1-e^{-sT_d}\right)} = \frac{1}{1+L_+\left(1-e^{-sT_d}\right)} \qquad (12)$$

At the stability limit cross over frequency ω_c, where $L_+ = -1$ the factor K_S takes a considerable positive phase advance into the closed-loop

$$K_S = \frac{1}{1+(-1)\left(1-e^{-sT_d}\right)} = \frac{1}{1-1+e^{-sT_d}} = e^{sT_d}\Big|_{\omega_c} = e^{j\omega_c T_d} \qquad (13)$$

This is the simple physical explanation of the success of the SMITH predictor [3].

Some early evaluations state that unfortunately the SMITH predictor is only good for tracking and not for disturbance rejection. This evaluation is wrong. The SMITH regulator was proposed for a one-degree of freedom (*1DOF*) closed-loop, so it is naturally not for *2DOF* purposes. The real problem of the SMITH regulator is that it allows the design of the closed-loop only via an indirect way by selecting $R_+ = T_+$, while the design procedure of the *G2DOF* scheme gives a direct procedure to design the independent tracking and disturbance rejection properties. This means that the original idea of SMITH was that a classical design of T_+ is necessary for the proper application. One must know that the YOULA parameterization and its application for regulator design was unknown for Otto SMITH when he invented his predictor.

V. The Discrete-Time Version of *G2DOF* Controllers

Although (11) suggests a proper way how to realize the SMITH regulator, it is not realistic to build any regulator containing the e^{-sT_d} delay element for continuous-time case. In the practice only the discrete-time (DT) version can be applied by computer realization. Consider the DT model of the CT process in the form of its pulse transfer function given by

$$G\left(z^{-1}\right)=G_+\left(z^{-1}\right)\overline{G}_-\left(z^{-1}\right)=G_+\left(z^{-1}\right)G_-\left(z^{-1}\right)z^{-d}$$
$$G=G_+\overline{G}_-=G_+G_-z^{-d} \tag{14}$$

where G_+ is stable and *ISR*, G_- is *IUU* and z^{-d} corresponds to the discrete time-delay, where *d* is the integer multiple of the sampling time. (In a practical case the factor G_- can incorporate the underdamped zeros and the neglected poles providing realizability, too). The optimal *ARS* regulator of the *G2DOF* scheme can be given now by

$$C_o=\frac{R_wK_w}{1-R_wK_wS}=\frac{Q_o}{1-Q_oG}=\frac{R_wG_wG_+^{-1}}{1-R_wG_wG_-z^{-d}} \tag{15}$$

which corresponds to the CT case of (5), furthermore (6) and (7) are formally exactly the same for DT case. The transfer characteristics of the closed-loop is now

$$y=R_rK_rGy_r+\left(1-R_wK_wG\right)w=R_rG_rG_-z^{-d}y_r+\left(1-R_wG_wG_-z^{-d}\right)w=y_t+y_d \tag{16}$$

Because the optimization of the embedded filters G_r and G_w requires special knowledge and practice of getting the solution from a *DE* and *NP* approximation, suboptimal design is mostly applied assuming $G_r=G_w=1$. In such cases the influence of the invariant process factors are not attenuated at all, so they appear in the closed-loop characteristics (15) directly. Such *G2DOF* control scheme is shown in Fig. 9.

It follows from the above discussion that it is not necessary to apply the classical SMITH predictor principle, instead it is more effective to use the regulator design procedure of the *G2DOF* controller scheme.

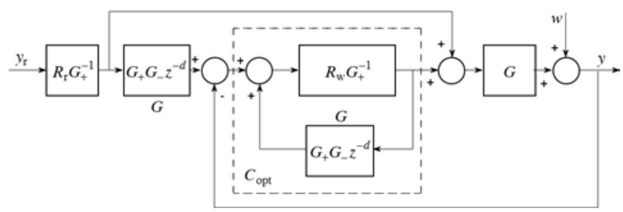

Fig. 9: Discrete-Time *G2DOF* Control System for the Suboptimal $G_r=G_w=1$ case

VI. Simple Examples

Example 1

Consider a very simple first order time-delay process

$$P=\frac{1}{1+10s}e^{-5s}\ ;\ P_+=\frac{1}{1+10s}\ ;\ \overline{P}_-=e^{-5s}\ ;\ P_-=1 \tag{17}$$

The tracking and disturbance rejection reference models are

$$R_r=\frac{1}{1+4s}\quad\text{and}\quad R_w=\frac{1}{1+2s} \tag{18}$$

Here $P_-=1$, therefore $G_r=G_w=1$ is the optimal selection for the embedded filters.

Design a YOULA-paramererized optimal regulator.

$$C_{opt}=\frac{R_wG_wP_+^{-1}}{1-R_wG_wP_-e^{-sT_d}}=\frac{1}{1-R_we^{-sT_d}}R_wP_+^{-1}=\frac{1}{1-\frac{1}{1+2s}e^{-5s}}\frac{1+10s}{1+2s}=\frac{(1+2s)(1+10s)}{1+2s-e^{-5s}} \tag{19}$$

and the optimal serial compensator is

$$R_rK_r=R_rG_rP_+^{-1}=R_rP_+^{-1}=\frac{1+10s}{1+4s} \tag{20}$$

Both transfer functions are realizable. Because $C_{opt}(s=0)=\infty$ the regulator is integrating obtained from the condition $R_w(s=0)=1$. The optimal final closed-loop is shown in Fig. 10. Although all blocks are realizable in this scheme it is very unrealistic that the real CT models of the true process are applied in a practical application. Here the real difficulty is the realization of the time-delay. So this example stands only to represent the *YP* based *G2DOF* design procedure.

It is easy to check that the closed-loop characteristics is

$$y_{opt}=R_re^{-sT_d}y_r+\left(1-R_we^{-sT_d}\right)w=\frac{1}{1+4s}e^{-5s}y_r+\left(1-\frac{1}{1+2s}e^{-5s}\right)w \tag{21}$$

according to the general theory.

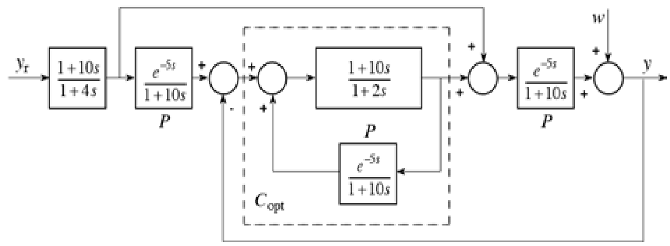

Fig. 10: The Designed Optimal Closed-Loop of the Example

Example 2

Consider the DT model of a very simple first order time delay process

$$G=\frac{0.2z^{-1}}{1-0.8z^{-1}}z^{-3}=\frac{0.2z^{-4}}{1-0.8z^{-1}}\ ;\ G_+=\frac{0.2z^{-1}}{1-0.8z^{-1}}\quad\text{and}\quad G_-=1 \tag{22}$$

It is required to speed up the process by a closed-loop.

Design a *YP* controller. Select the reference models

$$R_r=\frac{0.8z^{-1}}{1-0.2z^{-1}}\quad\text{and}\quad R_w=\frac{0.5z^{-1}}{1-0.5z^{-1}} \tag{23}$$

Because $G_-=1$, there is no optimization task, so the selections $G_r=1$ and $G_w=1$ are optimal. The optimal regulator is

$$C_{opt}=\frac{R_wG_wG_+^{-1}}{1-R_wG_wG_-z^{-d}}=\frac{1}{1-R_wz^{-d}}R_wG_+^{-1}=\frac{1}{1-\dfrac{0.5z^{-1}}{1-0.5z^{-1}}z^{-3}}\,\frac{0.5z^{-1}}{1-0.5z^{-1}}\,\frac{1-0.8z^{-1}}{0.2z^{-1}}=\frac{2.5\left(1-0.8z^{-1}\right)}{1-0.5z^{-1}-0.5z^{-4}} \tag{24}$$

and the serial compensator is

$$R_rG_+^{-1}=\frac{0.8z^{-1}}{1-0.2z^{-1}}\,\frac{1-0.8z^{-1}}{0.2z^{-1}}=\frac{4\left(1-0.8z^{-1}\right)}{1-0.2z^{-1}} \tag{25}$$

The optimal final closed-loop is shown in Fig. 11. Observe that $C_{opt}(z=1)=\infty$, i.e. the regulator is an integrating one, which follows from the condition $R_w(z=1)=1$.

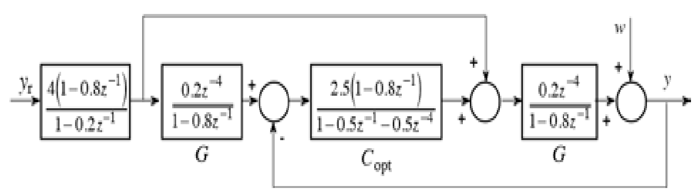

Fig.11: The designed optimal closed-loop of the example

The closed-loop characteristics is

$$y_{opt}=R_rz^{-d}y_r+\left(1-R_wz^{-d}\right)w=\frac{0.8z^{-1}}{1-0.2z^{-1}}z^{-3}y_r+\left(1-\frac{0.5z^{-1}}{1-0.5z^{-1}}z^{-3}\right)w=\frac{0.8z^{-4}}{1-0.2z^{-1}}y_r+\left(1-\frac{0.5z^{-4}}{1-0.5z^{-1}}\right)w \tag{26}$$

which exactly corresponds to our design goals.

This example shows that there is no applicability problem for DT regulator design. These filters are easy to be realized in a computer controlled system.

Example 3.

The continuous first order plant with significant time delay is given by the transfer function

$$P(s)=\frac{1}{1+10s}e^{-30s} \tag{27}$$

The plant is sampled with sampling time $T_s=5$ sec and a zero order hold is applied at its input. Let us design a *PI* controller ensuring about 60° of phase margin, a Smith predictor and a YOULA-parameterized controller. Compare the reference signal tracking and output disturbance rejection behaviour of the three control systems. Demonstrate the effect of time delay mismatch.

The pulse transfer function of the plant is

$$G(z)=\frac{0.3935}{z-0.6065}z^{-6} \tag{28}$$

The pulse transfer function of the *PI* controller [7] applying pole cancellation with a gain ensuring the required phase margin is

$$C_{PI}(z)=0.204\frac{z-0.6065}{z-1} \tag{29}$$

The SMITH predictor controller C_+ is designed for the delay free process as a *PI* controller and it is obtained as

$$C_+(z)=2.5\frac{z-0.6065}{z-1} \tag{30}$$

Then it is transformed to the SMITH predictor form according to the discretized version of (11).

$$C_s(z)=\frac{2.5z^7-1.516z^6}{z^7-0.01636z^6-0.9837} \tag{31}$$

In the case of the YOULA parameterized controller let us choose the disturbance filter

$$R_w(s)=\frac{1}{1+5s} \tag{32}$$

and the reference filter as

$$R_r(s)=\frac{1}{1+8s} \tag{33}$$

whose pulse transfer functions are

$$R_w(z)=\frac{0.6321}{z-0.3679} \text{ and } R_r(z)=\frac{0.4647}{z-0.5353}, \tag{34}$$

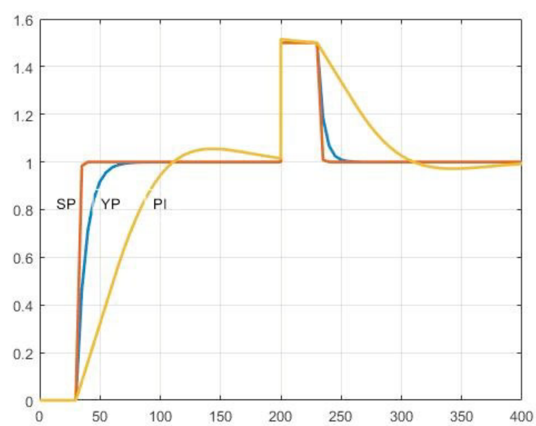

Fig. 12: Step response and disturbance rejection dynamics of the *PI*, SMITH and YOULA controllers

The YOULA parameter supposing $G_r = G_w = 1$ is

$$Q(z)=R_w(z)G_+^{-1}(z)=\frac{0.6321}{z-0.3679}\cdot\frac{z-0.6065}{0.3935} \tag{35}$$

Figure 12 shows the step response and a shifted step disturbance rejection of the three controllers.

It is seen that in case of significant time delay SMITH predictor and the YOULA parameterized controllers ensure significant acceleration compared to the *PI* controller.

Figure 13 demonstrates the effect of time delay mismatch in the case of the SMITH and the YOULA controllers. The time delay of the model is 30, while the time delay of the process is 33.

It is seen that the YOULA parameterized controller tolerates much better the inaccuracy of the parameter than the SMITH predictor. While the SMITH predictor is very sensitive to the inaccuracies in the parameters (it is not robust), the filters in the YOULA parameterized controller can be designed for robust behaviour [11].

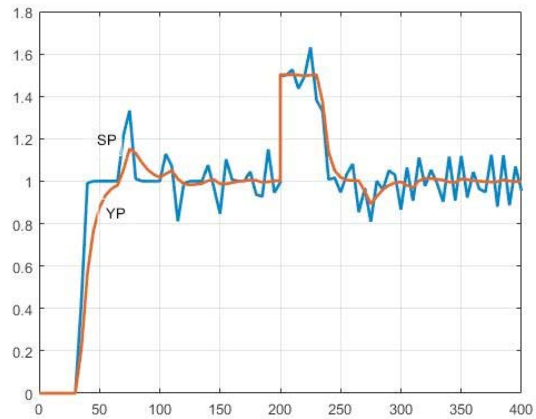

Fig. 13: The Effect of Time Delay Mismatch in Case of the SMITH and the YOULA Controllers

These are, of course, very simple examples standing only to present the simplicity of the *G2DOF* controller scheme, which should replace the classical approach of a SMITH predictor.

VII. Conclusions

The SMITH predictor is a classical method of handling time-delay in closed-loop control design. It is shown that this method is a subclass of the *YP* based *G2DOF* control scheme. An obvious drawback of the SMITH predictor is that the closed-loop properties can not be designed directly using simple algebraic methods, which is possible in the *G2DOF* structure. The *G2DOF* scheme allows even the optimal attenuation of the invariant process factors. The appropriate choice and design of the filters allows to influence such important properties as performance and robustness. So the paper suggests to use the newer methodology to design DT controllers for time-delay processes.

The role of the SMITH predictor remains important in the history of control engineering, because it was one of the first, easy to use and widely applied method to simply eliminate the influence of the delay in the design of closed-loop control properties. Nevertheless this method is sensitive to the accurate knowledge of the time delay.

The recent theoretical developments and easily applicable algebraic design methods allow to use more effective and more general controller design procedures.

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ASSOCIATE OF COMPUTER SCIENCE RESEARCH COUNCIL

ASSOCIATE OF COMPUTER SCIENCE RESEARCH COUNCIL is the membership of Global Journals awarded to individuals that the Open Association of Research Society judges to have made a 'substantial contribution to the improvement of computer science, technology, and electronics engineering.

> The primary objective is to recognize the leaders in research and scientific fields of the current era with a global perspective and to create a channel between them and other researchers for better exposure and knowledge sharing. Members are most eminent scientists, engineers, and technologists from all across the world. Associate membership can later be promoted to Fellow Membership. Associates are elected for life through a peer review process on the basis of excellence in the respective domain. There is no limit on the number of new nominations made in any year. Each year, the Open Association of Research Society elect up to 12 new Associate Members.

Benefit

To the Institution

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Career | Credibility | Reputation

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Career | Financial

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Career | Credibility | Reputation

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Financial

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Organize seminar/conference

Associates are authorized to organize symposium/seminar/conference on behalf of Global Journal Incorporation (USA). They can also participate in the same organized by another institution as representative of Global Journal. In both the cases, it is mandatory for him to discuss with us and obtain our consent. Additionally, they get free research conferences (and others) alerts.

Career | Credibility | Financial

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Get a remuneration of 15% of author fees

Associate members are eligible to join as a paid peer reviewer at Global Journals Incorporation (USA) and can get a remuneration of 15% of author fees, taken from the author of a respective paper.

Financial

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All members get access to 2 selected scientific museums and observatories across the globe. All researches published with Global Journals will be kept under deep archival facilities across regions for future protections and disaster recovery. They get 5 GB free secure cloud access for storing research files.

Associate	Fellow	Research Group	Basic
$4800 **lifetime designation**	$6800 **lifetime designation**	$12500.00 **organizational**	APC **per article**
Certificate, LoR and Momento 2 discounted publishing/year **Gradation** of Research 10 research contacts/day 1 **GB** Cloud Storage **GJ** Community Access	**Certificate,** LoR and Momento **Unlimited** discounted publishing/year **Gradation** of Research **Unlimited** research contacts/day 5 **GB** Cloud Storage **Online Presense** Assistance **GJ** Community Access	**Certificates,** LoRs and Momentos **Unlimited** free publishing/year **Gradation** of Research **Unlimited** research contacts/day **Unlimited** Cloud Storage **Online Presense** Assistance **GJ** Community Access	**GJ** Community Access

Preferred Author Guidelines

We accept the manuscript submissions in any standard (generic) format.

We typeset manuscripts using advanced typesetting tools like Adobe In Design, CorelDraw, TeXnicCenter, and TeXStudio. We usually recommend authors submit their research using any standard format they are comfortable with, and let Global Journals do the rest.

Alternatively, you can download our basic template from https://globaljournals.org/Template.zip

Authors should submit their complete paper/article, including text illustrations, graphics, conclusions, artwork, and tables. Authors who are not able to submit manuscript using the form above can email the manuscript department at submit@globaljournals.org or get in touch with chiefeditor@globaljournals.org if they wish to send the abstract before submission.

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Authors must ensure the information provided during the submission of a paper is authentic. Please go through the following checklist before submitting:

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2. Authors must accept the privacy policy, terms, and conditions of Global Journals.
3. Ensure corresponding author's email address and postal address are accurate and reachable.
4. Manuscript to be submitted must include keywords, an abstract, a paper title, co-author(s') names and details (email address, name, phone number, and institution), figures and illustrations in vector format including appropriate captions, tables, including titles and footnotes, a conclusion, results, acknowledgments and references.
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7. Manuscript submitted *must not have been submitted or published elsewhere* and all authors must be aware of the submission.

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2. Drafting the paper and revising it critically regarding important academic content.
3. Final approval of the version of the paper to be published.

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The corresponding author should mention the name and complete details of all co-authors during submission and in manuscript. We support addition, rearrangement, manipulation, and deletions in authors list till the early view publication of the journal. We expect that corresponding author will notify all co-authors of submission. We follow COPE guidelines for changes in authorship.

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Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

Declaration of funding sources

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Preparing your Manuscript

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for writing a good quality Computer Science Research Paper

Techniques for writing a good quality computer science research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of computer science then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10.Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

  - Single section and succinct.
  - An outline of the job done is always written in past tense.
  - Concentrate on shortening results—limit background information to a verdict or two.
  - Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

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Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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