Representation of TRIZ standard inventive solutions as a multilayer problem-solution network

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Abstract. Standard inventive solutions of TRIZ provide the guidance for resolving a large set of problems. In order to cover a wide range of problem types, there have to be a substantial number of standard inventive solutions which pose challenges for TRIZ practitioners to memorize them. Currently, TRIZ practitioners navigate in 76 standard inventive solutions with help of a simple categorization system, or with support of a question-based diagram to gradually narrow the standard inventive solution candidates. In this work, we propose a visual multilayer network graph combining with a rich taxonomy system to represent the list of standard inventive solutions. This approach helps users to quickly find standard inventive solutions that match their problem nature by leveraging the visual connections between standard inventive solutions and problem properties, as well as using semantic search in computer programs. The new method is implemented in the software TRIZ Flow to facilitate the choice of standard inventive solutions in daily problem solving tasks. The new representation of standard inventive solutions also paves the road to discover more standard inventive solutions in future research.

1. INTRODUCTION

Developed by Genrikh Altshuller, the Theory of Inventive Problem Solving (TRIZ) has served as a cornerstone of systematic innovation for over half a century. While many practitioners enter the methodology through the highly accessible 40 Inventive Principles - used primarily to resolve explicit technical contradictions, more complex, deeply embedded system inefficiencies require a higher level of abstraction. This is the domain of Substance-Field (Su-Field) Analysis and the subsequent **76 Standard Inventive Solutions** (SIS).

The Standard Inventive Solutions are designed to address systems where mechanical, thermal, or magnetic fields interact with physical substances in a manner that is either insufficient, excessive, or harmful. By applying these standards, engineers can reconfigure system architectures without relying on trial-and-error brainstorming.

However, a fundamental operational bottleneck persists: the sheer amount of information packed in 76 standard inventive solutions introduces severe cognitive friction. For a problem-solving matrix to be universally applicable across all engineering disciplines, it must be deeply comprehensive. Yet, memorizing and accurately deploying 76 abstract, multi-clause rules is a daunting task. Currently, practitioners navigate this space using either a basic five-class hierarchical list or manual, binary decision trees (e.g., "Is the system harmful? Yes/No"). These legacy tools are highly linear, rigid, and prone to inducing user fatigue, often resulting in premature solution selection. This paper proposes a transition from linear checklists to a multi-dimensional, visual graph approach to radically reduce cognitive load and improve solution accuracy.

2. LITERATURE REVIEW

1. Foundations of Su-Field Analysis

The theoretical foundation of the 76 Standard Inventive Solutions is heavily reliant on the accurate formulation of a Su-Field model. Terninko (2000a, 2000b) provided critical early literature dissecting the structural mechanics of these models, offering step-by-step guides for defining system components and mapping them to Altshuller's five original classes of standards (e.g., decomposing configurations, evolving systems, or utilizing ambient resources). More recently, Gadd (2011) offered an operational restructuring of the framework, simplifying the standards for modern design engineers by contextualizing them within "Level 3" inventive problems - scenarios that require introducing new elements from external industries to resolve technical bottlenecks.

2. Recent Developments in Digital TRIZ

As the limitations of manual TRIZ application became apparent, researchers shifted toward Computer-Aided Innovation (CAI). Yang et al. (2006) demonstrated early success in mapping standard inventive solutions using object-oriented XML architectures, effectively hard-coding the algorithmic nature of the solutions into software. More recent advancements have embraced semantic reasoning. Yan et al. (2022) utilized fuzzy logic ontology and Semantic Web Rule Language (SWRL) to build rule-based heuristic methodologies. Their work successfully automated the deduction of applicable inventive standards, narrowing down the search space algorithmically.

3. The Gap in Current Methodologies

While recent ontological and rule-based approaches have successfully automated the *backend* of Su-Field analysis, they obscure the systemic interconnectedness of the solutions from the human designer. The software acts as a "black box," outputting an answer without enriching the engineer's understanding of the solution space. The methodology presented in this paper bridges this gap by transforming backend taxonomic reasoning into an interactive, visual multilayer graph.

3. METHODOLOGY: THE RICH TAXONOMY SYSTEM

To construct a responsive graph, the standard inventive solutions must first be decoupled from their rigid classical groupings and re-classified within a "Rich Taxonomy System." Rather than relying solely on Altshuller's original Class 1 through 5, our methodology maps each of the 76 standards against a granular, multi-dimensional classification matrix. Each standard inventive solution is tagged simultaneously along **four independent dimensions**, creating a faceted taxonomy that enables flexible, multi-criteria navigation.

4. The Four Dimensions

The taxonomy employs four orthogonal classification dimensions. The first dimension preserves the classical grouping for backward compatibility, while three newly introduced dimensions provide functional, strategy-oriented, and resource-oriented perspectives.

Dimension 1 - Formal Class (d1): This dimension preserves Altshuller's original five-class hierarchy, maintaining continuity with classical TRIZ literature. It groups standard inventive solutions by their structural relationship to the Su-Field model lifecycle:

Value	Description
Class 1: Construction and Destruction of Substance-Field Models	Standards for building, completing, or dismantling basic Su-Field systems - addressing incomplete, excessive, or harmful interactions.
Class 2: Development of Substance-Field Models	Standards for evolving existing Su-Fields toward higher efficiency through chain/double models, Fe-Fields, dynamization, and rhythm coordination.
Class 3: System Transitions	Standards for macro-level architectural shifts - transition to bi-/poly-systems (supersystem level) or transition to microlevel phenomena.
Class 4: Detection and Measurement	Standards specifically aimed at detection, measurement, and monitoring problems, using bypasses, measurement Su-Fields, and Fe-Field sensing.
Class 5: Strategies for Simplification and Improvement	Meta-level strategies for introducing substances and fields more effectively when other standards face implementation constraints.

Dimension 2 - Problem State (d2): This dimension classifies the **nature of the deficiency or dysfunction** present in the Su-Field system before the standard inventive solution is applied. It answers the question: "*What is wrong with the current system?*"

Value	Description
Incomplete System	The Su-Field model is missing one or more required elements (substance or field) and cannot perform its intended function.
Excessive Action	The system delivers more action than required - the output is too strong, uncontrollable, or disproportionate.
Harmful Interaction	The Su-Field model produces a parasitic, destructive side-effect alongside (or instead of) the intended useful function.
System Complexity/Optimization	The system functions but is suboptimal in efficiency, controllability, or structural sophistication and requires evolutionary improvement.
Insufficient Interaction	The existing Su-Field interaction is too weak to achieve the desired effect; amplification or replacement is needed.
Measurement/Detection	The problem is not about changing the system behavior but about observing, measuring, or detecting a parameter or state change.

Dimension 3 - Strategic Action (d3): This dimension classifies the **type of inventive operation** the standard inventive solution prescribes. It answers the question: "*What should the engineer do?*"

Value	Description
Synthesize/Complete	Build or complete a Su-Field system by adding the missing substance, field, or interaction link.
Trim/Simplify	Remove, reduce, or simplify system elements - eliminate redundancy, use minimal resources, or collapse subsystems.
Protect/Neutralize	Shield a substance from harmful fields, introduce barriers, sacrificial elements, or counteracting fields to neutralize damage.
Enhance/Boost	Amplify an existing interaction by increasing controllability, dynamization, segmentation, rhythm coordination, or field structuring.
Synchronize/Pace	Coordinate the temporal rhythm of fields and substances to achieve resonance or interleave incompatible operations.
Differentiate/Transition	Execute a qualitative architectural change - transition to bi-/poly-systems, microlevel, phase-state changes, or opposite properties.
Measure/Detect	Apply a detection or measurement strategy - build measurement Su-Fields, use copies/models, or transition to Fe-Field sensing.

Dimension 4 - Filter Resources (d4): This dimension classifies the **type of physical resource** the standard inventive solution leverages or manipulates. It answers the question: "*What resources are involved in the solution?*"

Value	Description
Internal Substances/Fields	The solution works with substances and fields already present within the system boundary.
External Environment	The solution draws resources from the surrounding environment or supersystem.
Additives/Particles	The solution introduces foreign substances, particles, additives, or protective layers.
Frequencies & Fields	The solution manipulates field properties - magnetic, electric, electromagnetic fields, resonance frequencies, or field structures.
Phase/State Transitions	The solution exploits changes in aggregate state, dual-phase properties, or reversible physical transformations.
Copies/Models/ Supersystems	The solution uses copies, models, images, or integrates the system into a supersystem or bi-/poly-system architecture.

5. Multi-Dimensional Tagging

By assigning these four dimension values as metadata tags to each standard inventive solution, we transition the TRIZ framework from a flat hierarchical list into a **queryable, multi-faceted relational database**. A single standard inventive solution can be located from any of four independent entry points: by its classical class, by the problem state it addresses, by the strategic action it prescribes, or by the resource type it manipulates. This allows flexible navigation to the practitioner when selecting standard inventive solutions based on different characteristics of the problem.

6. Complete Taxonomy Listing

The following subsections present the full classification of all 76 standard inventive solutions. Section C.1 lists every standard grouped by its traditional Formal Class (d1). Sections C.2–C.4 then present the three new dimensions in a compact summary format: one table per dimension, where each row is a dimension value and the second column enumerates all SIS numbers classified under that value.

1. Standard Inventive Solutions by Formal Class (Dimension 1)

Class 1: Construction and Destruction of Substance-Field Models (13 SIS)

SIS	Name
1.1.1	Synthesis of a substance-field system
1.1.2	Improving interactions by introducing additives into the objects
1.1.3	Improving interactions by introducing additives into the system
1.1.4	Use the environment to improve interactions
1.1.5	Modify the environment to improve interactions
1.1.6	Providing minimal effect of action
1.1.7	Providing maximal effect of action
1.1.8	Use the selectively maximal mode
1.2.1	Eliminate harmful interaction by introducing a foreign substance
1.2.2	Eliminate harmful interaction by modifying existing substances
1.2.3	Eliminate harmful action of a field by introducing a sacrificial substance
1.2.4	Eliminate harmful effects by a new counteracting field
1.2.5	"Turning off" a magnetic field

Class 2: Development of Substance-Field Models (23 SIS)

SIS	Name
2.1.1	Transition to chain Su-Field
2.1.2	Transition to double Su-Field
2.2.1	Transition to more controllable fields
2.2.2	Segmentation of the substance
2.2.3	Transition to capillary-porous substance
2.2.4	Dynamization of the Su-Field
2.2.5	Changing the structure of the field
2.2.6	Changing the structure of the substance
2.3.1	Coordination of rhythms of the field and the substance
2.3.2	Coordination of rhythms of the fields that are used
2.3.3	Coordination of incompatible or previously independent activities
2.4.1	Transition to Proto-Fe-Field
2.4.2	Transition to Fe-Field
2.4.3	Using ferromagnetic fluids
2.4.4	Using capillary-porous substances in Fe-Fields
2.4.5	Transition to complex Fe-Field
2.4.6	Transition to Fe-Field using the external environment
2.4.7	(Fe-Fields) Using physical effects
2.4.8	Dynamization of the Fe-Field
2.4.9	Changing the Fe-Field structure
2.4.10	Coordination of rhythms of the Fe-Field
2.4.11	Transition to E-Field (Su-field with interacting electrical currents)
2.4.12	Using electro-rheological liquids

Class 3: System Transitions (6 SIS)

SIS	Name
3.1.1	Transition to bi- and poly-systems
3.1.2	Development of links in bi-systems and poly-systems
3.1.3	Increasing the difference between elements of bi-/poly-systems
3.1.4	Trimming of bi-systems and poly-systems
3.1.5	Opposite properties of the system and its parts
3.2.1	Transition to microlevel

Class 4: Detection and Measurement (17 SIS)

SIS	Name
4.1.1	Modifying the system so there is no need to measure or detect
4.1.2	Measuring a copy or an image
4.1.3	Successive change detection
4.2.1	Creating the measurement Su-Field
4.2.2	Transition to the complex measurement Su-Field
4.2.3	Transition to the measurement Su-Field based on the external environment
4.2.4	Utilizing resources of the environment
4.3.1	(Intensifying measurement Su-Fields) Using the physical effects
4.3.2	Using the resonance of the controlled object
4.3.3	Using the resonance of the integrated object
4.4.1	Transition to measurement Proto-Fe-Fields
4.4.2	Transition to measurement Fe-Field
4.4.3	Transition to complex measurement Fe-Field
4.4.4	Transition to measurement Fe-Field based on external environment
4.4.5	(Transition to measurement Fe-Fields) Using the physical effects
4.5.1	Transition to measurement bi- and poly-systems
4.5.2	Transition to the measurement of derivatives

Class 5: Strategies for Simplification and Improvement (17 SIS)

SIS	Name
5.1.1	Bypass
5.1.2	Separating the product into interacting parts
5.1.3	Using a substance for a limited time
5.1.4	Using inflatable structures and foam
5.2.1	Using the existing fields
5.2.2	Using the field of the external environment
5.2.3	Using existing substances as field sources
5.3.1	Substituting the phase state of the substance
5.3.2	The dual phase-state of the substance
5.3.3	Using phenomena accompanying the phase changes
5.3.4	Transition to the two-phase state of the substance
5.3.5	Using interactions between parts (phases) of the system
5.4.1	Using the reversible physical transformations
5.4.2	Strengthening the output field
5.5.1	Obtaining the substance particles by decomposition
5.5.2	Obtaining the substance particles by combining
5.5.3	The simplest methods to obtain substance particles

2. Classification by Problem State (Dimension 2)

Problem State	Standard Inventive Solutions (SIS)	Count
Incomplete System	1.1.1, 1.1.2, 1.1.3, 1.1.4, 1.1.5, 5.1.1, 5.1.2	7
Excessive Action	1.1.6, 1.1.7, 1.1.8, 5.1.3, 5.1.4	5
Harmful Interaction	1.2.1, 1.2.2, 1.2.3, 1.2.4, 1.2.5	5
Insufficient Interaction	2.2.1, 2.2.2, 2.2.3	3
System Complexity/Optimization	2.1.1, 2.1.2, 2.2.4, 2.2.5, 2.2.6, 2.3.1, 2.3.2, 2.3.3, 2.4.1, 2.4.2, 2.4.3, 2.4.4, 2.4.5, 2.4.6, 2.4.7, 2.4.8, 2.4.9, 2.4.10, 2.4.11, 2.4.12, 3.1.1, 3.1.2, 3.1.3, 3.1.4, 3.1.5, 3.2.1, 5.2.1, 5.2.2, 5.2.3, 5.3.1, 5.3.2, 5.3.3, 5.3.4, 5.3.5, 5.4.1, 5.4.2, 5.5.1, 5.5.2, 5.5.3	39
Measurement/Detection	4.1.1, 4.1.2, 4.1.3, 4.2.1, 4.2.2, 4.2.3, 4.2.4, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.5.1, 4.5.2	17

3. Classification by Strategic Action (Dimension 3)

Strategic Action	Standard Inventive Solutions (SIS)	Count
Synthesize/Complete	1.1.1, 1.1.2, 1.1.3, 1.1.4, 1.1.5, 2.1.1, 2.1.2	7
Protect/Neutralize	1.1.7, 1.1.8, 1.2.1, 1.2.2, 1.2.3, 1.2.4, 1.2.5	7
Trim/Simplify	1.1.6, 3.1.4, 5.1.1, 5.1.2, 5.1.3, 5.1.4, 5.2.1, 5.2.2, 5.2.3, 5.5.1, 5.5.2, 5.5.3	12
Enhance/Boost	2.2.1, 2.2.2, 2.2.3, 2.2.4, 2.2.5, 2.2.6, 2.3.2, 2.3.3, 2.4.1, 2.4.2, 2.4.3, 2.4.4, 2.4.5, 2.4.6, 2.4.7, 2.4.8, 2.4.9, 2.4.10, 2.4.11, 2.4.12	20
Synchronize/Pace	2.3.1	1
Differentiate/Transition	3.1.1, 3.1.2, 3.1.3, 3.1.5, 3.2.1, 5.3.1, 5.3.2, 5.3.3, 5.3.4, 5.3.5, 5.4.1, 5.4.2	12
Measure/Detect	4.1.1, 4.1.2, 4.1.3, 4.2.1, 4.2.2, 4.2.3, 4.2.4, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.5.1, 4.5.2	17

4. Classification by Filter Resources (Dimension 4)

Filter Resources	Standard Inventive Solutions (SIS)	Count
Internal Substances/Fields	1.1.1, 1.1.2, 1.1.3, 1.1.6, 1.1.7, 1.1.8, 2.1.1, 2.1.2, 3.1.2, 3.1.3, 3.1.4, 4.3.1, 4.3.2, 4.3.3, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.5.2, 5.2.1	20
External Environment	1.1.4, 1.1.5, 2.2.5, 5.2.2, 5.2.3	5
Additives/Particles	1.2.1, 1.2.2, 1.2.4, 1.2.5, 2.2.4, 2.2.6, 4.2.1, 5.1.1, 5.1.2, 5.1.3, 5.1.4	11
Frequencies & Fields	1.2.3, 2.2.1, 2.3.1, 2.3.2, 2.3.3, 2.4.1, 2.4.2, 2.4.3, 2.4.4, 2.4.5, 2.4.6, 2.4.7, 2.4.8, 2.4.9, 2.4.10, 2.4.11, 2.4.12, 4.2.2, 4.2.3, 4.2.4, 4.5.1	21
Phase/State Transitions	2.2.2, 2.2.3, 3.2.1, 5.3.1, 5.3.2, 5.3.3, 5.3.4, 5.3.5, 5.4.1, 5.4.2	10
Copies/Models/Supersystems	3.1.1, 3.1.5, 4.1.1, 4.1.2, 4.1.3, 4.4.1, 5.5.1, 5.5.2, 5.5.3	9

7. Observations on Distribution

The distribution of standard inventive solutions across the three new dimensions reveals important patterns about the TRIZ framework's design emphasis. The dominance of "System Complexity/Optimization" in Problem State (51% of all standards) confirms that the classical TRIZ framework is primarily oriented toward **evolutionary improvement** of existing systems. The heavy concentration of "Frequencies & Fields" in Filter Resources reflects TRIZ's industrial-era origins in electromagnetic engineering. These distributional insights, made visible only through the multi-dimensional taxonomy, enable researchers to identify both the strengths and the coverage gaps in the current standard inventive solutions framework.

4. THE ITERATIVE DIMENSIONAL FILTERING FRAMEWORK

The Rich Taxonomy System enables a highly transparent, user-driven **Iterative Dimensional Filtering Framework**. This framework allows practitioners to navigate the 76 standard inventive solutions systematically by leveraging the independent classification dimensions (Problem State, Strategic Action, and Filter Resources) as structural filters.

1. Iterative Candidate Elimination

The core operational principle of this framework is the progressive reduction of the solution space. Instead of presenting all 76 standard inventive solutions simultaneously, the taxonomy permits engineers to query the database along multiple orthogonal axes. The search workflow functions as an iterative filtering process:

> **Step 1: Identifying the Problem State (d2):** The user begins by analyzing the current Su-Field model deficiency and selecting the corresponding Problem State (e.g., Harmful Interaction). This single selection immediately eliminates the vast majority of inapplicable standards, narrowing the candidate pool from 76 to a highly focused subset (e.g., 5 solutions).
>
> **Step 2: Selecting the Strategic Action (d3):** The user then determines the desired inventive direction (e.g., Protect/Neutralize). This filters the active subset further, matching the chosen action type.
>
> **Step 3: Filtering Resources (d4):** Finally, the user enters system constraints by filtering the available or permissible resources (e.g., Additives/Particles vs. Frequencies & Fields).

By sequentially specifying values across these distinct dimensions, the user gradually narrows down the candidates. This deterministic approach transforms standard inventive solution selection from a subjective, trial-and-error lookup into a precise, step-by-step elimination process.

2. Cognitive Friction Reduction and Selection Accuracy

By partitioning the search criteria into discrete, easily identifiable vectors (What is wrong? What action should be taken? What resources are available?), the framework eliminates the cognitive load associated with reading and parsing all 76 abstract descriptions. This structured path guides the engineer directly to the standard inventive solutions that match the exact physical and functional constraints of their specific engineering problem, ensuring high selection accuracy and facilitating rapid choice of the appropriate inventive standard.

5. SOFTWARE REALIZATION: TRIZ FLOW

To validate the multilayer graph methodology, we developed the software **TRIZ Flow**. The software is designed to operate as an interactive, physics-directed environment rather than a static decision tree. **TRIZ Flow** incorporates multiple TRIZ algorithms assisting TRIZ practitioners in applying TRIZ methodologies for problem solving. The newly developed visually multilayer graph of TRIZ standard inventive solutions is an interactive module to be plugged in workflows supported by **TRIZ Flow**.

A practitioner navigates a *TRIZ Standard Inventive Solutions* session in **TRIZ Flow** by switching between dimensions, analyzing values matching with the problem to be solved to narrow down the search, and can compare their deficient Su-Field model with the illustrated Su-Field model in standard inventive solutions.

As the problem properties are defined, the semantic engine activates in real-time. The user interface displays a clustered 2D network graph where irrelevant solutions fade into the background, and highly applicable standard inventive solutions (which match currently selected filters) are highlighted, clickable to provide more details. The user can add custom filters by typing text in the search box. Semantic search capabilities integrated into the user interface allow practitioners to continuously filter the graph dynamically. An illustrated example is provided in Figure 1, where the user has applied filter “Excessive Action” in the dimension of Problem State, and filter “Trim/Simplify” in the dimension of Strategic Action.

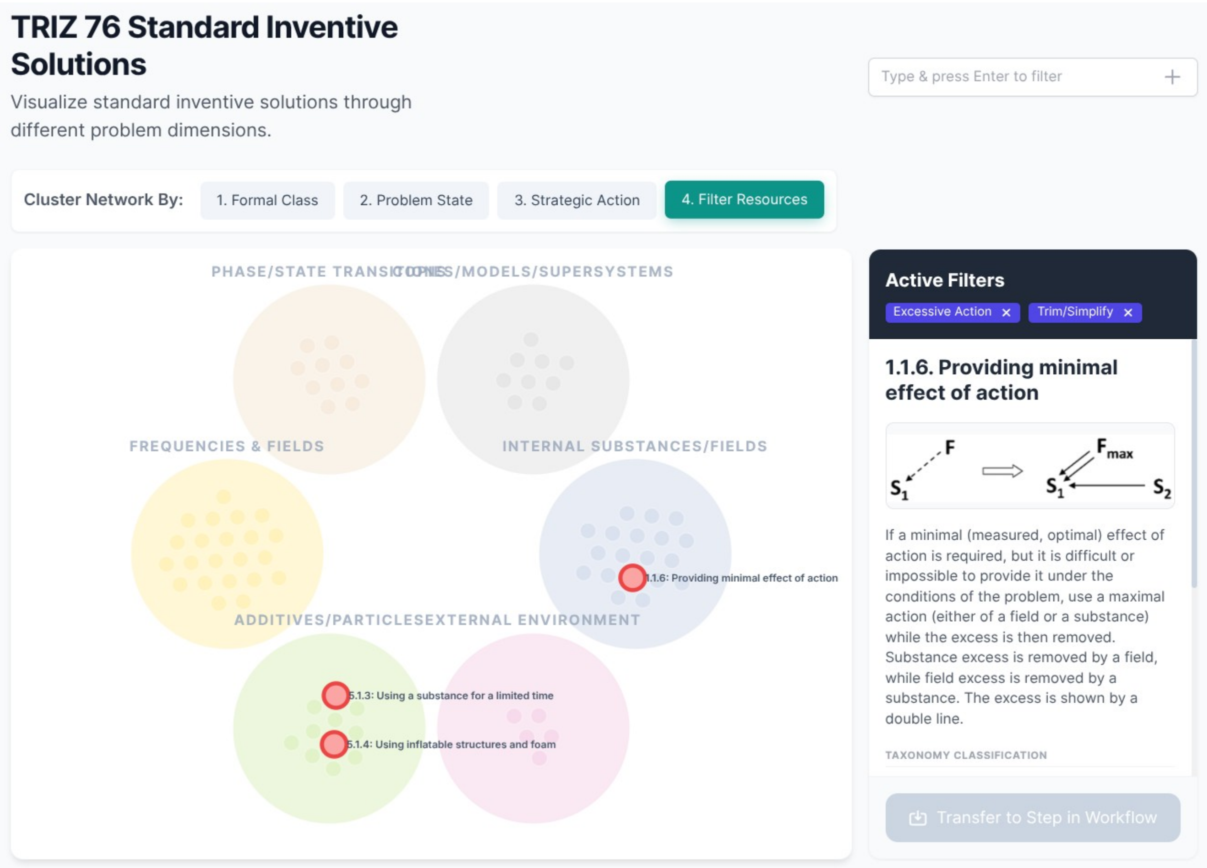

Figure 1. User interface of the multilayer network visualization of TRIZ standard inventive solutions

6. DISCUSSION: DISCOVERING NEW STANDARD INVENTIVE SOLUTIONS

Beyond immediate problem-solving, the graphical representation of TRIZ standard inventive solutions offers a profound analytical advantage: the ability to execute network topology analysis.

Historically, TRIZ assumes a closed system of 76 standard inventive solutions. However, by treating these solutions as a network graph, researchers can mathematically analyze structural voids, degree centrality, and isolated subgraphs. If, over time, a specific cluster of problem properties frequently occurs in modern engineering (e.g., in quantum computing or nanomaterials) but exhibits a "missing edge link" to clusters in several dimentions, the graph visually highlights an *inventive blindspot*.

Consequently, the new representation of TRIZ standard inventive solutions serves as a predictive model. It reveals the exact topological coordinates where classical TRIZ fails to provide a prediction where the "77th" or "78th" standard inventive solutions must be developed by the academic community. The author expects the proposed network topology will help the TRIZ community to discover new standard inventive solutions, similarly to the effect of the Periodic Table in predicting new elements.

7. CONCLUSION AND FUTURE WORK

The **TRIZ Flow** framework successfully addresses the cognitive friction inherent in classical Su-Field analysis and the 76 Standard Inventive Solutions. By combining a rich metadata taxonomy with a visual multilayer network graph and semantic search, the framework transforms standard inventive solutions from a daunting memorization exercise into an intuitive, algorithmic discovery process.

Future research will focus on formal empirical validation. We propose conducting comprehensive user-testing studies comparing the time-to-resolution and solution novelty of novice engineers utilizing **TRIZ Flow** against seasoned experts utilizing classical printed text trees. Furthermore, ongoing analysis of the graph's structural voids will be utilized to propose extensions to Altshuller's original 76 solutions, ensuring TRIZ remains robust in the face of modern technological paradigms.

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