A Declarative Dialectical Layer for Argument Construction and Synthesis Prediction

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Abstract. We introduce a declarative dialectical layer for structured argument construction, aimed at making dialectical reasoning systematic rather than ad hoc. The approach extends beyond traditional acceptability semantics by imposing explicit constraints on thesis–antithesis relations, generating four complementary components (constructive and exaggerated forms of each) and enforcing consistency between them. By integrating LLM-based argument generation with rule-based filtering, we bridge unstructured semantic output and formal reasoning. The framework is evaluated on two domains: sugar production in photosynthesis and the Deepwater Horizon (Macondo) safety case, demonstrating its ability to identify system blind spots and derive high-feasibility corrective transitions. The results show that constraint-driven dialectical reasoning improves the robustness and completeness of argument construction in complex systems.

Keywords: Dialectical Reasoning, Rule-Based Systems, Bipolar Argumentation, Synthesis Prediction

1 Introduction

Argument construction is a key challenge in computational reasoning [1, 2]. While frameworks such as ASPIC+ [3], procedural dialogue games [4], and Bipolar Argumentation (BAFs) [5, 6] provide rigorous acceptability semantics for agent-based interactions, they remain largely agnostic to the internal structure of argument generation. In contrast, our approach introduces a declarative dialectical layer (Fig. 1) that shifts the focus from evaluation to the construction phase.

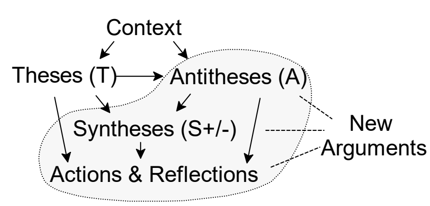


Fig. 1. Argument construction scheme

Rather than introducing new acceptability semantics, this layer imposes explicit relational constraints and synthesis conditions (Table 1). By integrating LLM-based generation with these rule-based constraints, the framework enforces a structured representation of complementary relations—a requirement essential for modeling complex systems [7], yet typically not captured by purely statistical or unconstrained procedural approaches.

Table 1. Generative rules for dialectical synthesis prediction

Constraint	**Rule**
Polarity	Every thesis (T) has at least one antithesis (A)
Antithesis selection (simple assertions)	The antithesis is typically a direct negation of the thesis.
Antithesis selection (complex systems)	Multiple antitheses typically exist. Identification of relevant antitheses proceeds iteratively, often revealing counteracting processes that are initially overlooked.
Tetradic	Every T–A interaction yields pairs of complementary upsides (T+, A+) and exaggerations / downsides (T–, A–), such that T+ directly contradicts A- and T- directly contradicts A+
Diagonal Entanglement	Changing any tetrad's component induces change in its contradiction, such that sums of their idealized modalities (M) remain zero: $M(T+) + M(A-) = M(T–) + M(A+) = 0$
Equal Modalities	Positive synthesis (S+) occurs iff all components have equal absolute modalities (M): $M(T+) = –M(T-) = M(A+) = –M(A-)$.
Empirical Inequalities	Empirical conditions of positive synthesis (S+): $K_S(T+) – K_S(T-) \approx K_S(A+) – K_S(A-) \geq 0.1$, positive poles $K_S(T/A+) > 0.4$, negative poles $K_S(T/A-) < 0.6$ (K_S = concept's average complementarity to T and A, $(K_T+K_A)/2$)
Apex Tetrad	Among several possible tetrads, the best one has: $\text{Min } [(K_S (T+) – K_S (A+))^2 + (K_S (T-) – K_S (A-))^2]$ $\text{Max } [K_S (T+) + K_S (A+) – K_S (T-) – K_S (A-)]$ $\text{Max } [K_T (T+)]$, $\text{Max } [K_T (A+)]$
Control Statements	The following statements must make sense: T+ without A+ yield T-; A+ without T+ yield A-. Conceptual Coherence (CC) must exceed 0.7
Equal Sign Synthesis	Positive synthesis occurs between T+ and A+. Negative synthesis occurs between T- and A-
Different Sign Isolation	No direct interaction is possible between T/A, T+/A-, T-/A+ (because they are direct oppositions or contradictions), T+/T-, A+/A- (because they are different levels of the same phenomena)
Positive Synthesis (S+)	A system exhibits positive synthesis iff it increases dimensionality while preserving stability, distinction, and normative coherence.
Negative Synthesis (S-)	A system exhibits negative synthesis iff it maximizes existing dimensions through dominance or oscillation, resulting in faster formation but finite lifespan
Apex Coherence	The apex synthesis S+/- must lie within the convex hull (or semantic centroid) of its valid sub-syntheses

Circular Causality	S+ occurs iff T- is converted into A+ and A- is converted into T+, both acting in sync
Transitions' definitions	Ac = transition of T into A; Re = Transition of A into T; Ac+ = Transition T- into A+; Re+ = Transition of A- into T+; Ac- = Transition of T+ into A-; Re- = Transition of T- into A+.
Multi-Thesis Oppositions	In a circular ordering of the 2n elements {T1 … Tn, A1 … An}, each Ti and Ai must occupy diametrically opposite positions.
Transitions' Matrix Concept	Given n theses, the optimization solution is found within the (4n^2 - 2n) transitions {Tr} mapping each negative pole (Ti-/Ai-) to all positive poles (T1+, …, A1+, …).

2 Declarative Dialectical Layer

2.1 Polarity Constraint

Table 1 states that every thesis *T* has at least one antithesis *A*. This implies that *A* is a necessary counterpart of *T* rather than an optional addition, and that examining *A* can reveal mechanisms and counterforces implicit in *T*. This perspective enables a form of forensic reasoning often absent in conventional analyses. For example, when evaluating a social or engineering system, standard logic typically asks, *"What could go wrong?"* (relying on past experience), whereas dialectical reasoning asks, *"What process is currently complementing or counteracting our apparent success?"* This shift helps uncover systemic interactions that may otherwise remain hidden.

2.2 Antithesis Selection

All cases can be subdivided into two broad groups. The first group consists of assertive binary choices, where direct negation or apex antitheses (i.e., general negating reference points) are often sufficient (e.g., True vs. False, Approval vs. Disapproval). The second group consists of exploratory or systemic cases, where concepts have multiple roles and simple negation is insufficient (e.g., Love, Justice, Sugar, Car). In such cases, identifying an antithesis requires examining the function of the thesis within a larger system. Rather than asking "What negates T?", one should ask "What opposes or counteracts the role T plays?" Figure 2 exemplifies this analysis for T = Sugar in Photosynthesis.

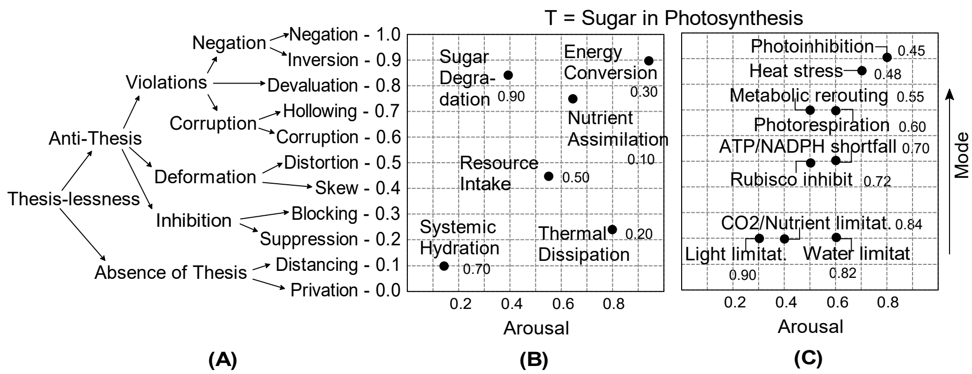
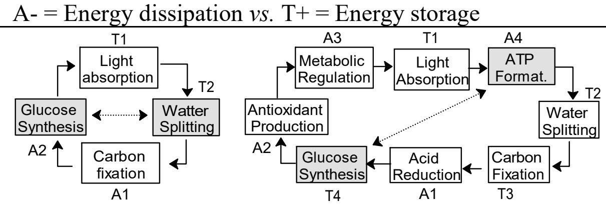


Fig. 2. Taxonomy of antitheses

Scheme (A) shows the clustering of antitheses into a universal taxonomy tree. Moving from left to right gradually reveals specific mechanisms of opposition, culminating in Scheme (B), which plots antitheses along two axes: Mode (interaction mechanism) and Arousal (activation level). The apex antithesis is typically found in the top right-most position (Arousal ≈ Mode ≈ 1.0). However, this antithesis may not be the optimal choice from the viewpoint of heuristic similarity to Thesis-lessness (indicated by the values in parentheses). Furthermore, one may encounter "operational" antitheses better categorized as narrow pathologies (S-) rather than drivers of healthy growth [8] (Plot C). Therefore, we employ the step-wise definition in Table 2, combining rule-based and mechanistic evaluation.

Table 2. Determining antitheses in complex systems

N	**Constraint**	**Example (T = Sugar in photosynthesis)**
1	A functionally opposes T	A = Energy conversion / Sugar degradation
2	A+ must contradict T-, A- must contradict T+	A+ = Energy transduction *vs.* T- = Resource depletion; A- = Energy dissipation *vs.* T+ = Energy storage
3	In a cyclic loop, A and T must be placed diagonally to each other	
4	T+ with A+ yield S+	S+ = Biomass production
5	T w/o A+ and A w/o T+ produce pathologies (S-)	(T − A+) = Chlorosis and stunted growth. (A − T+) = Photobleaching and oxidative leaf damage

The first two constraints represent rule-based conditions typically met with a single prompt. In most practical cases, this is sufficient because structural strengths are opposed by a multitude of processes (Fig. 2B) rather than a single static entity (Fig. 2C). However, when these criteria prove insufficient, the remaining three constraints must be considered, implying iterative analysis discussed in later sections.

2.3 Tetradic Constraints

The core structural assumption of our method represents the semantic "diagonality" requirement in Table 2 (the rule that “A+ must contradict T-, A- must contradict T+”). Therefore, once an antithesis is selected, this relationship is evaluated more rigorously, using considerations in Fig. 3.

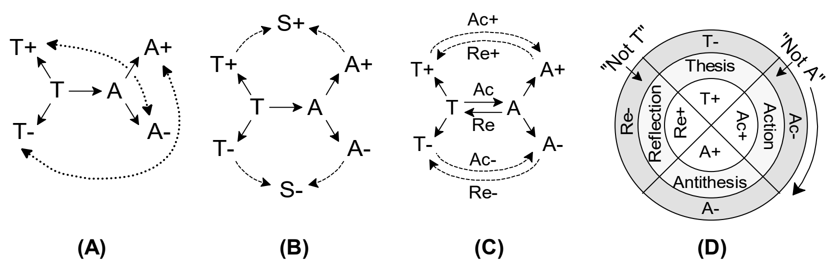


Fig. 3. Generation of dialectical components

Scheme A shows that each starting component (T and A) generates two additional components—a positive (+) and a negative (−)—which are bound by the three constraints (see Table 3).

Table 3. Determining T+, T-, A+, A- components

N	Constraint	T = Sugar, A = Energy convers	CC*
1	T+/A+ are constructive, balancing developments that enhance upsides of opposition	Energy storage (T+) enhances Energy sufficiency (A+), which is an upside of Energy conversion (A)	0.72
		Energy Sufficiency (A+) enhances Energy storage (T+), which is an upside of Sugar formation (T)	0.95
2	T-/A- are overdevelop-ments or exaggerations of the parent concept, and simultaneously underdeve-lopments of its opposition	Resource depletion (T-) is overdeveloped Sugar formation (T) & underdeveloped Energy Conversion (A)	0.85
		Energy dissipation (A-) is overdeveloped Energy conversion (A) and underdeveloped Sugar Formation (T)	0.92
3	T+ must directly contradict A-, and T- must directly	Energy storage (T+) directly contradicts Energy dissipation (A-)	0.88

	contradict A+ (shown by dotted arrows in Fig. 3A)	Resource depletion (T-) directly contradicts Energy sufficiency (A+)	0.90

* Conceptual Coherence estimated by GPT 5.2

The primary source of uncertainty lies in selecting the initial component from which to construct the tetrad. Once this choice is made, the remaining components are established using rules 1-3 from Table 3 applied in almost any sequence. (Each component can be represented by multiple alternative framings, but these alternatives occupy a restricted semantic space.)

2.4 Modality Alignment

This constraint provides a further formalization of the diagonal oppositions (implied in Tables 2 and 3). Each concept possesses an argumentative strength and affective intensity, which we represent as a scalar Modality (M). A balanced system requires symmetry in absolute modality values:

$$M(\mathrm{T+}) = -M(\mathrm{T-}) = M(\mathrm{A+}) = -M(\mathrm{A-}). \qquad (1)$$

Modalities can be approximated *via* average complementarities to the Thesis (K_T) and Antithesis (K_A):

$$K_S = (K_T + K_A)/2 \qquad (2)$$

Fig. 4 illustrates typical values for balanced (A) and distorted (B, C) systems.

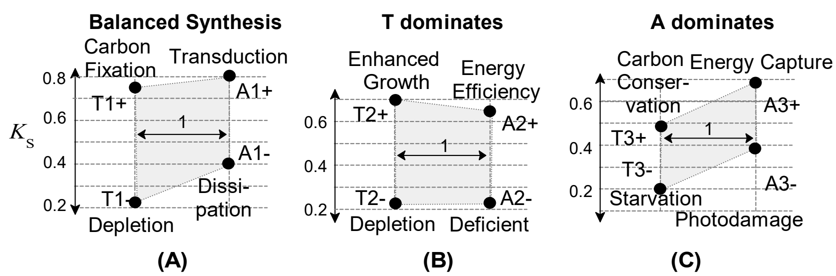


Fig. 4. Complementarity diagrams for T = Sugar, A = Energy Conversion

Scheme A shows the highest K_S for both T+ and A+, but somewhat lower tetragon's rectangularity defined by the pole coordinates. The final decision is determined by a set of symmetry requirements (summarized in Table 4), with their relative importance tuned via empirical weights.

Table 4. Complementarity-Based Symmetry Requirements

Rule	Expression	Rationale	Pathologies
Maximum Complementarity	max K_S (T+), max K_S (A+), K_S (T+) ≈ K_S (A+)	S+ potential	$K_S(+) \leq 0.5$ $\lvert K_S(T+) - K_S(+)\rvert > 0.1$
Maximum Rectangularity	min $[(K_S (T+) – K_S (A+))^2 + (K_S (T-) – K_S (A-))^2]$	Eq. (1)	Skewed shape (Fig. 4C)
Maximum Area	max $[K_S (T+) + K_S (A+) – K_S (T-) – K_S (A-)]$	Dialectical "work"	K_S(T-/A-) ≈ > K_S(T+/A+)

Control Statements. Components of balanced system must generate logically coherent statements of the following form (Table 5):

T+ without A+ yields T-, while A+ without T+ yields A-

Table 5. Control Statements

Case	T = Sugar, A = Energy conversion	CC*
(A) Balanced system	Carbon fixation (T_1^+) without Regulated transduction (A_1^+) yields Resource depletion (T_1^-)	0.90
	Regulated transduction (A_1^+) without Carbon fixation (T_1^+) yields Oxidative dissipation (A_1^-)	0.93
(B) Biased toward T	Enhanced Growth (T_2^+) without Energy Efficiency (A_2^+) yields Resource Depletion (T_2^-)	0.85
	Energy Efficiency (A_2^+) without Enhanced Growth (T_2^+) yields Energy Deficit (A_2^-)	0.70
(C) Biased toward A	Resource Conservation (T_3^+) without Strong Energy Capture (A_3^+) yields Carbon Starvation (T_3^-)	0.87
	Strong Energy Capture (A_3^+) without Resource Conservation (T_3^+) yields Photodamage (A_3^-)	0.94

* Conceptual Coherence estimated by GPT 5.2

2.5 Synthesis

Positive synthesis (S+) produces a new emergent quality, whereas negative synthesis (S−) merely maximizes specific quantities. While both types theoretically complement each other, in practice S− imitates the appearance of S+ while actively suppressing it. In ML terms, S+ mirrors a well-regularized model where structural constraints (T) keep the learning process (A) from drifting into catastrophic forgetting or gradient explosions. Conversely, S− states simulate this regulation—effectively "deceiving" the observer—by achieving superficial stability at the cost of actual model robustness.

Equal Sign Synthesis. Figure 3(B) illustrates that synthesis occurs exclusively between like-signed components. Positive synthesis takes place between T^+ and A^+, while negative synthesis occurs between $T^−$ and $A^−$. No direct interaction is possible between undifferentiated or oppositely signed poles—such as T and A, T+ and A-, or T- and A+—because these represent direct oppositions or contradictions. Similarly, no direct interaction is possible between T^+ and $T^−$ or between A^+ and $A^−$, as these correspond to different developmental levels of the same phenomenon rather than complementary counterparts.

Outcome Classification. Table 6 illustrates that S+ and S- can be viewed as developmental trajectories of maturation or pathology, respectively.

Table 6. Typical modes of Positive and Negative Syntheses for T = Sugar Formation

	Sa+ (Process)	**Sb+ (Structure)**	**Sc+ (Normative)**
Core Principle	Self-Regulation and Resilience	Bounded Coupling	Invariant Preservation:
General Schema	Remaining stable under shocks	Preserving distinction while creating new relations	Preserving core values while creating new meanings
Sugar formation in photosynthesis	Homeostasis between the Light Reactions and the Calvin Cycle	Thylakoid Mem-brane enabling H^+ gradient and e-transport	Stable ATP/ NADPH production despite fluctuating light
Sa- (Distortion via dominant T)	Rigidity (frozen order) – Photoinhibition	Care becomes control – Membra-ne Hyper-polarization	Moral absolutism, dogmatism – Metabolic Locking
Sb- (Erosion via dominant A)	Loss of feed- back, burnout – Photobleaching	Detachment, alienation - Lysis / Uncoupling	Value hollowing, instrumentalism - Dissipative Leakage
Sc- (Deregulation via T/A oscillation)	Crisis recovery cycles - Stomatal Oscillations	Push-pull bonds, cling withdraw – Antenna Quenching	Cynicism, disenga-gement – Retrogra-de Signaling

When applied to photosynthesis (as described in classic textbooks [8]), S+ represents biological health: for instance, Bounded Coupling (Sb+) is physically instantiated by the Thylakoid membrane, which maintains a distinct proton gradient while simultaneously enabling the relation of electron transport. Conversely, S- outcomes represent the pathological states mapped in Fig 1C, where stress-induced 'Thesis-lessness' leads to systemic failures like Photoinhibition or Erosion.

2.6 Transition Rule (Circular Causality)

Positive synthesis (S+) arises if and only if two complementary transitions occur simultaneously (see Fig. 3 C): an exaggerated thesis component (T-) is transformed into a constructive antithesis component (A+), and an exaggerated antithesis component (A-) is transformed into a constructive thesis component (T+). Together, these paired transitions form a closed loop of circular causality, which constitutes the true source of self-regulation.

Prediction of Ac and Re Components. Ac and Re can be generated by simple prompts (*e.g.,* for Ac+: "suggest how to transform T- into A+"). The obtained tetrad (Ac+, Ac-, Re+, Re-) must obey all the same symmetry rules that were applied for T/A components in Tables 3 and 4 (*e.g.*, Ac+ must directly contradict to Re-, while Ac- must directly contradict to Re+.). Our main goal however is generation of actionable advice in the form of Ac+ and Re+. Fig. 5 shows that all such advices can be clustered using two general scales.

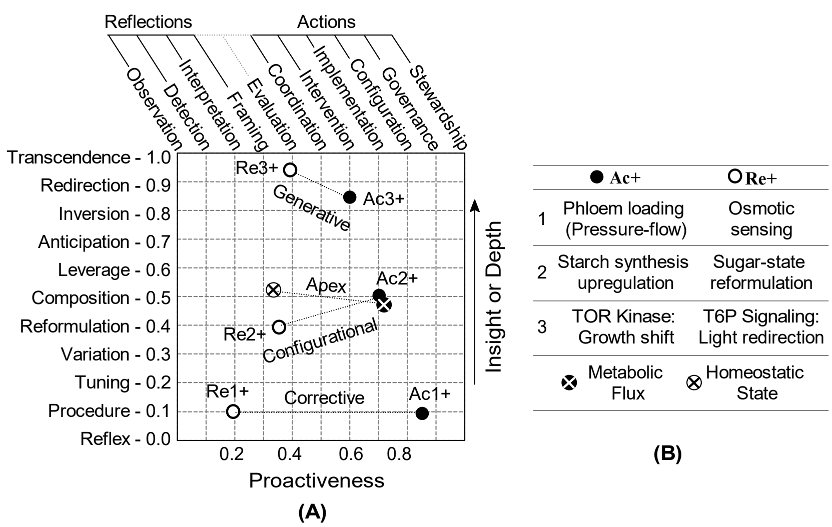


Fig. 5. Universal taxonomy of Ac/Re+ exemplified for T = Sugar, A = Energy Conversion

Here Proactiveness and Insight (or Depth, Smartness, Leverage) avoid forceful decisions, because Ac+ and Re+ must retain subtlety and flexibility for balancing each other. Becoming too forceful means changing own polarization from positive into negative. These taxonomies are universal and they help to increase variety of Ac+/Re+ steps during AI generation.

2.7 Multi-Thesis Conflict Resolution

When two or more theses interact, each must be converted into optimum tetrad, and transitions of each downside into all upsides must be generated. For instance, Fig. 6 illustrates migration from one to two theses system

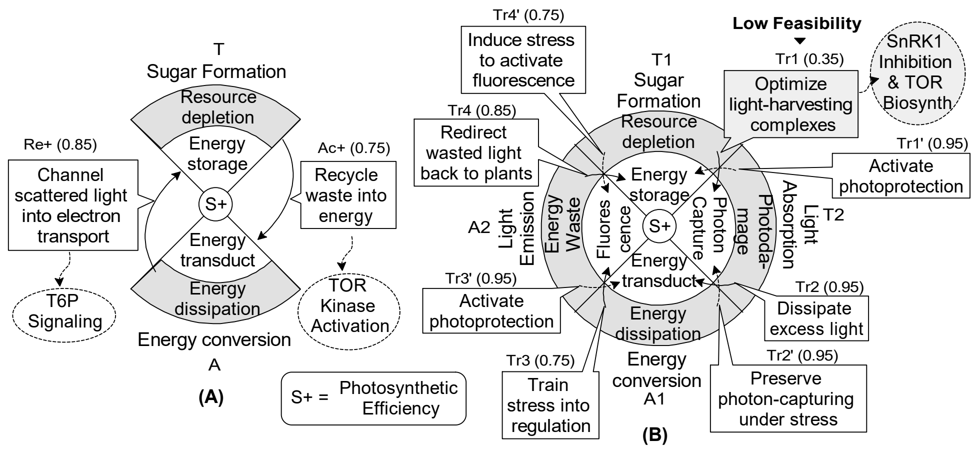


Fig. 6. Dialectical wheels for T = Sugar Formation, A = Energy Conversion.

Scheme A shows conflict resolution *via* Ac3+ and Re3+ steps from Fig. 5. The dotted arrows show mechanism refinement via iterative prompting. Scheme B considers an additional T/A pair (Light Absorption/Emission), where oppositions are placed diagonally to each other, creating "vortex synthesis" in the center of circular causation. This increases the feasibilities of most transition steps due to transition from generative Ac+/Tr+ steps to corrective. But for the very first step (Tr1) we obtain very low feasibility, signifying that the considered two-thesis system is incomplete. While the similar step in Scheme A (Ac+) reaches F=0.85 by using a "pre-programmed biochemical reflex" via kinases, this fails in Scheme B due to the system's higher complexity and broader goal. Consequently, the system must resort to structural remodeling (*e.g.*, creating new proteins) which is hardly possible due to the incompleteness of the system.

The problem can be solved by adding new theses to scheme B, until all feasibilities are acceptable. For this we must first identify the major steps of the entire system as shown in Fig. 7.

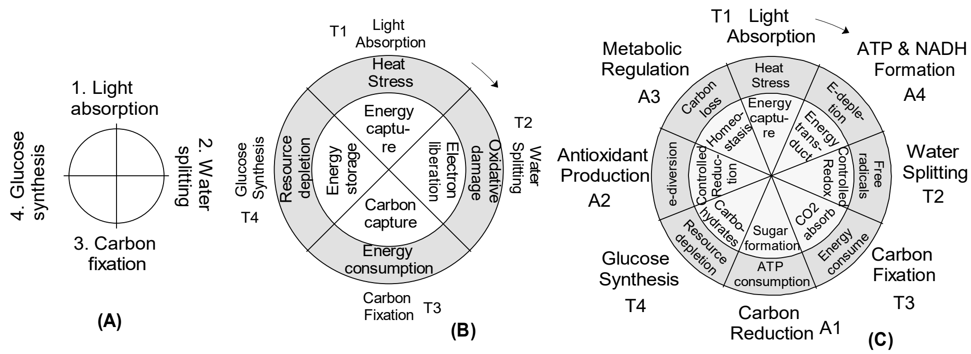


Fig. 7. Dialectical wheels for Photosynthesis analysis

Here, scheme A identifies the 4 major steps reflecting the most essential cycle of a given system. (A typical prompt: "suggest 4 major steps describing a given system in terms of circular causation"). Scheme B makes sure that diagonal positions balance each other (T1+ opposes T3-, T3+ opposes T1-; same for the T2/T4 pair). Scheme C converts each T into a tetrad (T+, T-, A+, A-) and circular causation. The 4 theses with fixed positions in scheme A yield 8 variants of valid circular causations in scheme C. All causations can be ranked by their practical feasibility. The best sequences can be used to identify the functional opposition in Table 2, and missing steps in Fig. 6. The obtained wheel then must be provided with Tr-Matrix showing how each negative pole (Tx- or Ax-) can be converted into all positives (T1+, …, A1+, …). N theses yield ($4N^2 - 2N$) transitions that is enough to optimize any given system.

2.8 Dialectical Reasoning Workflow

Figure 8 summarizes the dialectical layer, which functions as an augmented expert system for autonomous or supervised refinement.

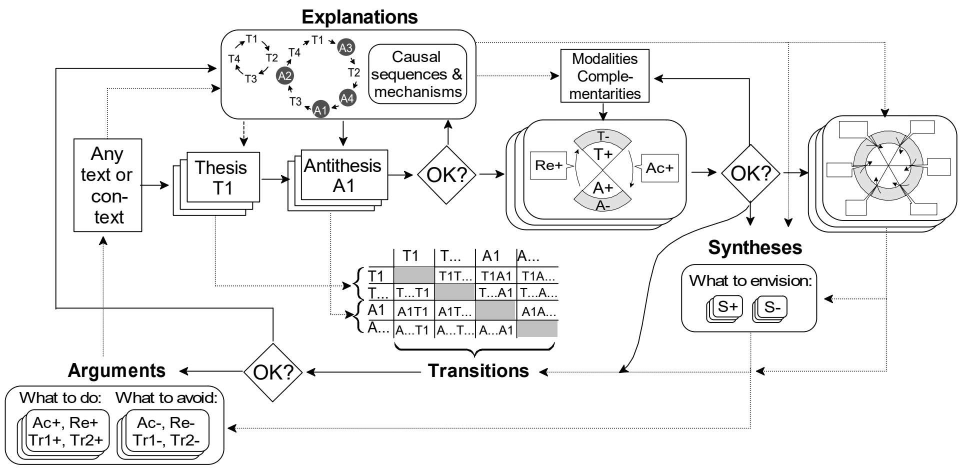


Fig. 8. Dialectical reasoning workflow

The process extracts Theses (T1, …, Tn) and pairs them with Antitheses (A1, …, An), validated via the Explanations module for causal grounding. Validated pairs expand into Tetradic structures (T±, A±), where the system checks Modalities and Complementarities for structural balance. A second gate verifies this alignment before the tetrads trigger Actions (Ac+) and Reflections (Re+). These map onto Dialectic Wheels to derive Transitions and predict synthesis. This recursive architecture manages up to four concurrent theses, refining them into Arguments that address both causal necessity and system blind spots.

3 Implementation and Use Case

The core part of this algorithm was implemented in the "Eye Opener" app using Claude Sonnet 4.5 engine [9]. It utilizes a hybrid reasoning pipeline, where LLM-based candidate generation is combined with rule-based constraints from Table 1.

To validate the framework, we applied it to the 2010 Macondo oil spill [10], a benchmark offshore engineering failure. The primary challenge in this case was not a lack of data, but the failure of binary reasoning to account for the "blind spots" created by operational pressures. Our framework addresses these limitations by treating rule violations not as external failures, but as structurally necessary antitheses that can be transformed into stabilizing mechanisms.

We used the 380-page Commission report [11] to extract the four core safety recommendations (Theses in Table 7).

Table 7. Starting Theses and Antitheses

Uploaded Theses	**Antitheses (suggested by Eye Opener)**
T1 = Halt displacement if pressure tests are anomalous	A1 = Displacement permitted despite test anomalies
T2 = Cement integrity must be independently verified before proceeding	A2 = Proceed based on operator's internal assessment
T3 = Blowout preventer (BOP) must meet verified functional redundancy standards	A3 = Relay on single-layer protection without verification
T4 = Formal stop-work authority with mandatory escalation protocol	A4 = No stop-work authority

Each thesis was provided with antithesis (2nd column in Table 7). These were converted into a tetrad as exemplified in Table 3, yielding circular causality maps exemplified in Fig. 9.

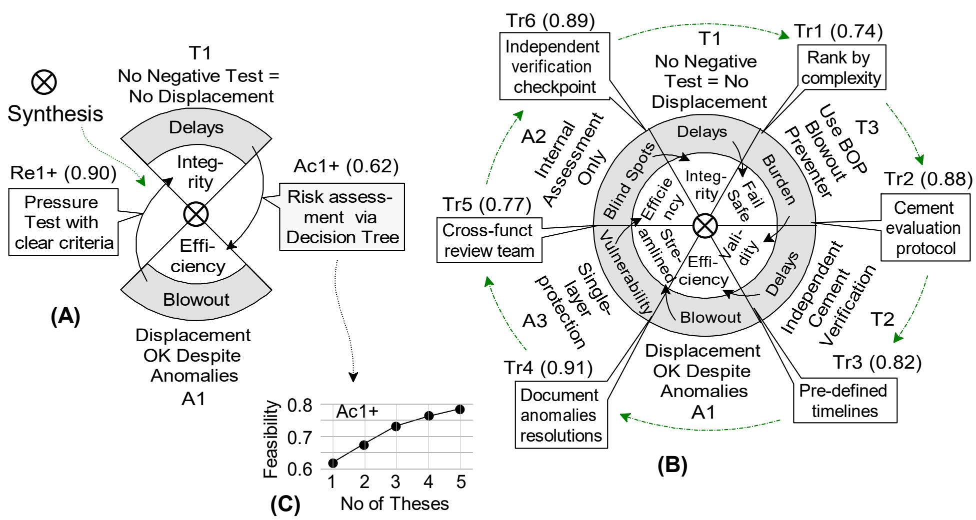


Fig. 9. Dialectical wheels for Macondo blowout case.

T1 – T3 represent the original recommendations, A1 – A3 their antitheses (violations). Downsides of each segment are transformed into upsides of the next segment through transition steps (Tr1–Tr6), creating a spiral convergence toward the center, where synthesis occurs.

Most of these steps exhibit high practical feasibility (estimated by simple prompting and shown in parentheses). Five such steps (representing a 20% novelty rate among generated transitions) were absent or only implicitly suggested in the Commission's report, serving as actionable "bridges" across identified operational gaps (Table 8).

Table 8. Actionable additions to existing recommendations

Suggested Tr step	Baseline Gap (Commission Report)	Dialectical Logic (Value-Add)
A4- to T1+: Mandatory pre-shift briefings where anyone can raise concerns (0.93)	Report suggests "culture," but lacks a timed protocol.	Converts vague intent into a mandatory time-locked mechanism.
T3- to T4+: rapid safety teams with delegated authority (0.81)	Accountability is noted, but not delegated real-time authority.	Reduces the latency between anomaly detection and decision.
A2- to A3+: checklist fast, escalate automatically (0.84)	Focuses on barrier failure, not standardized handled triggers.	Removes reliance on hierarchy/improvisation during crises.
T2- to T3+: parallelize cement verification with BOP testing (0.87)	Safety is treated as a sequential bottleneck.	Preserves integrity while removing the "pressure to skip" (A+)

As shown in Fig. 9C, these transitions reinforce one another, forming a convergent topology that supports self-regulating behavior. This demonstrates that the proposed method enables systematic transformation of local failures into coordinated system-level improvements. Fig. 10 summarizes our findings in relation to the complete state-space of possible transitions.

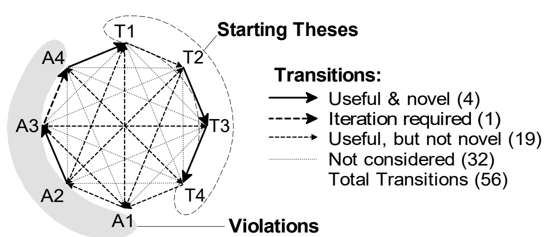


Fig. 10. Comparative topology of synthesized transitions.

The analysis reveals a fundamental structural gap in the Commission report: the discrepancy between retrospective blame (identifying T and A poles) and proactive synthesis (generating Tr paths). Our transitions fill the "dead zone" between static safety rules and operational reality, providing the "how" of systemic stabilization that was missing in the baseline expert analysis.

4 Conclusion

We introduced a declarative dialectical layer that shifts argumentation from evaluation to structured construction. By enforcing complementary relations between opposing components, the framework enables systematic identification of pathological distortions and synthesis conditions. Applied to the Macondo blowout case, the framework demonstrated a generative capacity to fill "structural gaps" in expert reports, identifying novel, high-feasibility operational transitions (Tr) that were absent in the baseline analysis. These findings support the role of dialectical complementarity in complex systems [7] and demonstrate how integrating rule-based structure with LLM generation provides a principled framework for autonomous knowledge discovery and self-regulating reasoning in complex domains.

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