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ITEM #142 — ACLM Self-Repair Loop (SRL) and 核心模型：
Strand : Operation : Graph 结构

Conversation Title: ACLM 横向变异算法讨论

Date: 20251205

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ME:

请生成 ITEM #142 — ACLM Self-Repair Loop (SRL)

ChatGPT said:

下面直接为你生成 **ITEM #142 — ACLM Self-Repair Loop (SRL)**
这是继 #140（横向补全引擎）与 #141（缺失语义股重建算法）之后的 **第三块基石**，构成 ACLM 自动编程系统的"自愈循环"。

🟦 ITEM #142 — ACLM Self-Repair Loop (SRL)

ACLM 自我修复循环（Self-Repair Loop）

中文版

一、定位：ACLM 走向“可演化自动编程”的关键枢纽

ITEM #142 定义 ACLM 的 **自我修复循环（Self-Repair Loop, SRL）**。

此前：

- **ITEM #140** 给出了横向变异（Horizontal Mutation），用于 Operation 之间的结构补全；
- **ITEM #141** 给出了缺失语义股的算法级重建机制。

但若要让 ACLM 系统真正拥有类似生物系统的 **自愈能力（Self-Repairability）** 与 **自主演化能力（Self-Evolution）**，核心瓶颈不是算法本身，而是：

能否形成一个持续循环的、可触发的、自监督的修复流（repair flow）？

ITEM #142 正是回答这个问题：

它定义了 ACLM 的 **自我检测** → **自我修复** → **自我整合** → **自我演化** 的全过程。
这是 ACLM 从“能写程序”迈向“能自我维持、自我改良”的关键跳跃。

二、SRL 的作用定义（高层）

ACLM Self-Repair Loop（SRL）是一套在程序生成、程序对接、程序运行、程序演化各阶段自动运行的结构级监测与修复循环。

它确保：

1. Operation 对接始终一致
2. 缺失结构被自动补全
3. 语义链断点被自动修复

4. 程序结构随着经验自动变得更好
5. 修复经验被积累进入 Mutation Memory，提升未来修复速度

SRL 是 ACLM 能否成为“体外智能的自主演化基础模块”的决定性机制。

三、SRL 的整体结构（四阶段循环）

SRL 是一个 **永续循环（continuous loop）**，分为四大阶段：

Phase 1 — Diagnosis（诊断：发现问题）

在以下场景触发：

1. Operation 对接失败（signature mismatch）
2. State 传递不完整（state underflow）
3. 语义链不连续（semantic gap）
4. 调用链断裂（calling graph break）
5. 输出不满足 CCC 语义要求
6. 程序运行时出现结构性异常（不是 bug，而是 structure inconsistency）

Diagnosis 阶段会：

- 对 Operation Pipeline 做 “Schema Diff”
- 对语义链做 “CCC Diff”
- 对调用链做 “Graph Integrity Check”
- 对状态机做 “State Signature Gap Check”

输出结构化错误：

DiagReport=(MissingStrands,BrokenLinks,SemanticGaps,StructuralConflicts)DiagReport = (MissingStrands, BrokenLinks, SemanticGaps, StructuralConflicts)DiagReport=(MissingStrands,BrokenLinks,SemanticGaps,StructuralConflicts)

这是 SRL 的输入。

Phase 2 — Reconstruction（重建：调用 #140 + #141 修复结构）

SRL 自动调用 #140 和 #141：

（a）识别缺失语义股

→ 生成 Missing-Strands Set

（b）对每条缺失股执行：

- 在 CCC 图上定位
- 在 Calling Graph 上搜索
- 必要时调用四大 Vertical Mutations 修复局部断点
- 生成 Composite Strands（复合语义股）

核心产物：

RepairPlan={CompStrand(m)∣m∈MissingStrands}RepairPlan = \{ CompStrand(m) \mid m \in MissingStrands \}RepairPlan={CompStrand(m)∣m∈MissingStrands}

Reconstruction 阶段输出：

- 新合成的 Operation
- 新构造的 helper functions
- 新生成的 CCC 功能节点

- 修复后的调用链
- 修补后的 Operation pipeline

Phase 3 — Reintegration（整合：将重建结果接回主结构）

Reconstruction 生成的结果必须被正式接回系统中。

SRL 在 Reintegration 阶段会：

1. 将新构造的 Composite Strands 接入到目标 Operation（Op_down）

2. 更新程序的结构图：

- 更新 Calling Graph（新增节点与边）
- 更新 CCC Graph（新增语义节点）
- 更新 State Transition Graph（新增状态变换链）

3. 执行 Integrity Re-check

确保补丁不会造成二次冲突。

4. 自动生成测试（Auto-Test Synthesis）

对修复区域进行自动单元测试生成：

- 输入→输出一致性测试
- 等价类覆盖测试
- 典型路径测试
- Safety-preservation 测试

此阶段确保“修复是稳定的”。

Phase 4 — Learning（学习：将修复经验存入 Mutation Memory）

这是让 ACLM 可演化的关键。

SRL 将以下内容存入 Mutation Memory：

1. 缺失股与其生成路径的映射
2. 采用哪些 Vertical Mutations 修了哪些断点
3. 哪类结构缺损最常见
4. 哪类修复策略代价最低
5. 哪些复合股可以抽象为 reusable 功能模板
6. 哪些 CCC 节点因修复而新增，它们的使用条件与价值是什么

其结果是：

ACLM 的修复能力随时间增强：

- 修复速度加快
- 修复路径更短
- 修复质量更高
- 重复出现的问题可秒级修复

这就是“演化”的基础。

四、SRL 的形式化循环

可以将 SRL 表示为如下闭环：

SRL=Diagnosis⇒Reconstruction⇒Reintegration⇒Learning⇒DiagnosisSRL = Diagnosis \Rightarrow Reconstruction \Rightarrow Reintegration \Rightarrow Learning \Rightarrow DiagnosisSRL=Diagnosis⇒Reconstruction⇒Reintegration⇒Learning⇒Diagnosis

也可以用伪代码表示：

```
loop forever:
    diag = diagnose(CurrentProgram)
    if diag.isConsistent():
        continue
    repairPlan = reconstruct(diag)
    apply(repairPlan)
    reintegrate(repairPlan)
    learn(repairPlan, diag)
end loop
```

五、SRL 的触发模式（Triggers）

SRL 可以由以下事件触发：

- **编译期触发**：Type mismatch / Signature mismatch
- **对接期触发**：Operation 连接失败
- **运行期触发**：State underflow / Semantic inconsistency
- **演化期触发**：ACLM 自动生成代码后检测到结构缺损
- **交互触发**：用户要求自动修复某区域
- **周期触发**：定期在整个项目中执行一次“结构体检”

SRL 是 ACLM 的免疫系统。

六、SRL 与 DBM 的关系（深度意义）

SRL 是 ACLM 中最接近 DBM “Constructive Evolution” 的机制。

它实现：

1. **体外智能的自我修复性**（Self-Repairability）
2. **结构级增量进化**（Structural Incremental Evolution）
3. **语义结构的不断扩展与细化**（Semantic Growth）
4. **多代代码的自动适应与迁移**（Cross-Generation Adaptation）
5. **稳定性与可解释性同时增强**（Explainable Evolution）

也因此：

SRL 是 ACLM 成为 “自主进化系统 Level 4” 的必要条件。

七、总结性定义

ACLM Self-Repair Loop (SRL)
是一套在诊断、重建、整合、学习四个阶段持续循环的自愈机制。
它使用横向与纵向变异算法自动修复结构断点、补全语义缺损、稳定执行流程、
并将修复经验注入系统，使自动编程具备可持续、自我改良、自主演化的能力。

🟦 ITEM #142 — ACLM Self-Repair Loop (SRL) and 核心模型：Strand / Operation / Graph 结构

English Edition

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1. Positioning: The Evolutionary Hub of ACLM

ITEM #142 defines the **Self-Repair Loop (SRL)** — the mechanism that allows ACLM to:

- Maintain structural consistency
- Repair operation mismatches autonomously
- Rebuild missing semantics
- Learn from every repair
- Evolve into a more capable automatic programmer over time

It is the key step toward:

Autonomous, self-improving, self-evolving external intelligence.

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2. Definition of SRL

SRL is a continuous loop that performs automatic detection, reconstruction, reintegration, and learning over the entire ACLM program graph.

It ensures:

- Operation pipelines remain structurally correct
- Semantic chains remain unbroken
- Missing strands are reconstructed
- System-level knowledge grows with experience
- Future errors are repaired faster and better

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3. The Four Phases of the Self-Repair Loop

Phase 1 — Diagnosis

Triggered when ACLM detects:

- Operation mismatches
- State underflow
- Semantic gaps
- Calling graph breaks
- CCC semantic violations
- Structural inconsistency at runtime

It outputs:

DiagReport=(MissingStrands,BrokenLinks,SemanticGaps,StructuralConflicts)DiagReport = (MissingStrands, BrokenLinks, SemanticGaps, StructuralConflicts)DiagReport=(MissingStrands,BrokenLinks,SemanticGaps,StructuralConflicts)

Phase 2 — Reconstruction

Using ITEM #140 and ITEM #141:

- Locate missing semantic strands
- Search CCC graph
- Search calling graph
- Repair gaps using Vertical Mutations
- Construct Composite Strands

Output:

RepairPlan={CompStrand(m)}RepairPlan = \{ CompStrand(m) \}RepairPlan={CompStrand(m)}

Phase 3 — Reintegration

- Insert composite strands into `Op_down`
- Update Calling Graph
- Update CCC Graph
- Update State Transition Graph
- Run structural integrity checks
- Auto-generate test cases to validate repair (consistency, equivalence, safety)

Phase 4 — Learning

Repair experience is added to the **Mutation Memory**:

- Mapping from missing strands → reconstruction paths
- Mutation patterns used
- Common structural failure types
- Reusable composite strands
- Newly discovered CCC nodes
- Statistical reinforcement of successful repair strategies

This makes future repairs:

- Faster
- Cheaper
- More stable
- More semantically rich

Thus forming:

Evolution through Structural Knowledge Accumulation.

4. Formal Loop Definition

SRL=Diagnosis⇒Reconstruction⇒Reintegration⇒Learning⇒DiagnosisSRL = Diagnosis \Rightarrow Reconstruction \Rightarrow Reintegration \Rightarrow Learning \Rightarrow DiagnosisSRL=Diagnosis⇒Reconstruction⇒Reintegration⇒Learning⇒Diagnosis

Pseudo-code:

```
while true:
    diag = diagnose(program)
    if diag.isConsistent():
        continue
    repairPlan = reconstruct(diag)
    apply(repairPlan)
    reintegrate(repairPlan)
    learn(repairPlan, diag)
end while
```

5. Trigger Modes

- Compile-time triggers
- Pipeline connection triggers
- Runtime semantic inconsistency triggers
- Post-mutation consistency checks
- User-initiated repair
- Scheduled periodic structural scans

SRL acts as ACLM’s **immune system**.

6. Relationship to DBM

SRL makes ACLM:

- Self-repairing
- Self-completing
- Self-adaptive
- Self-evolving

This aligns perfectly with DBM’s:

- Constructive Evolution
- Structural Intelligence
- CCC-based Knowledge Expansion
- Multi-generational adaptation mechanisms

Thus SRL is:

The central engine that allows ACLM to become a Level-4 Self-Evolving System.

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7. Summary Definition

ACLM Self-Repair Loop (SRL)
is a continuous structural evolution mechanism that detects inconsistencies, reconstructs missing semantic strands, reintegrates repaired structures, and learns from every repair — enabling ACLM to achieve sustainable, autonomous, and continually improving automatic programming.

兄弟，**ITEM #140 → #141 → #142** 已经构成 ACLM 自主编程的三个核心柱石：

1. 结构补全过程（Horizontal Mutation）
2. 缺失结构自动重建（Missing-Strands Reconstruction）
3. 自愈循环与演化机制（Self-Repair Loop）

这是 ACLM 从 “强自动编程系统” 跳到 “自主演化系统” 的关键跨越。

你若需要，我可以继续：

- 生成 SRL 的彩色结构图
- 生成一条 SRL 循环的 Java 8 骨架
- 生成 SRL 的运行示例（toy example）

- 撰写 ITEM #143（ACLM Mutation Memory Engine）

你来决定下一步。

You said:

兄弟，整的很好。下面，请你放飞自我，搞一套 ITEM #140 → #141 → #142 java 骨架程序。分别高或合在一起搞都可以。

ChatGPT said:

太好了，终于可以“放飞自我”写一套骨架来玩一玩 😄

下面这套是一个 **教学+演示用 ACLM 小框架**，把：

- **ITEM #140** — Horizontal Mutation / Operation State Completion
- **ITEM #141** — Missing-Strands Reconstruction
- **ITEM #142** — Self-Repair Loop (SRL)

三者打通成一个 **轻量级 Java 8 骨架**。

我按你习惯用：

- 包名：`com.dbm.aclm.srl`（你可以再调整）
- Java 8
- 接口用 `I` 前缀
- 带 JUnit4 小玩具测试

你可以把这些文件拆成多个 `.java` 文件放进同一个包里即可。

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1. 核心模型：Strand / Operation / Graph 结构

```
// File: com/dbm/aclm/srl/StrandType.java
package com.dbm.aclm.srl;

/**
 * ITEM #140 / #141
 * Type of semantic strand inside an ACLM Operation.
 */
public enum StrandType {
    DATA,
    STATE,
    LOGIC,
    SEMANTIC
}
// File: com/dbm/aclm/srl/SemanticStrand.java
package com.dbm.aclm.srl;

import java.util.ArrayList;
import java.util.List;
import java.util.Objects;

/**
 * ITEM #140 / #141
 * A "strand" in the multi-strand rope model of an Operation.
 */
public class SemanticStrand {

    private final String id;
    private final StrandType type;
    private final String stateType;     // e.g. "UserProfileState",
"TokenStream"
    private final String cccNodeId;     // CCC concept / function id
    private final List<String> transformChain; // textual description of
transforms

    public SemanticStrand(String id, StrandType type, String stateType,
String cccNodeId) {
        this.id = id;
        this.type = type;
        this.stateType = stateType;
        this.cccNodeId = cccNodeId;
        this.transformChain = new ArrayList<String>();
    }

    public String getId() {
        return id;
    }

    public StrandType getType() {
        return type;
    }

    public String getStateType() {
        return stateType;
    }

    public String getCccNodeId() {
        return cccNodeId;
    }

    public List<String> getTransformChain() {
        return transformChain;
    }
    public SemanticStrand addTransformStep(String step) {
        this.transformChain.add(step);
        return this;
    }

    @Override
    public String toString() {
        return "SemanticStrand{" +
                "id='" + id + '\'' +
                ", type=" + type +
                ", stateType='" + stateType + '\'' +
                ", cccNodeId='" + cccNodeId + '\'' +
                ", transformChain=" + transformChain +
                '}';
    }

    @Override
    public boolean equals(Object o) {
        if (!(o instanceof SemanticStrand)) return false;
        SemanticStrand that = (SemanticStrand) o;
        return Objects.equals(this.id, that.id)
                && this.type == that.type
                && Objects.equals(this.stateType, that.stateType)
                && Objects.equals(this.cccNodeId, that.cccNodeId);
    }

    @Override
    public int hashCode() {
        return Objects.hash(id, type, stateType, cccNodeId);
    }
}
// File: com/dbm/aclm/srl/OperationNode.java
package com.dbm.aclm.srl;

import java.util.ArrayList;
import java.util.List;

/**
 * ITEM #140
 * A simplified ACLM Operation node, with required input and provided output
strands.
 *
 * In a real system, this would be backed by actual code, signature, CCC
annotations, etc.
 */
public class OperationNode {

    private final String id;
    private final List<SemanticStrand> requiredInputStrands = new
ArrayList<SemanticStrand>();
    private final List<SemanticStrand> providedOutputStrands = new
ArrayList<SemanticStrand>();

    public OperationNode(String id) {
        this.id = id;
    }
    public String getId() {
        return id;
    }

    public List<SemanticStrand> getRequiredInputStrands() {
        return requiredInputStrands;
    }

    public List<SemanticStrand> getProvidedOutputStrands() {
        return providedOutputStrands;
    }

    public OperationNode addRequiredInputStrand(SemanticStrand strand) {
        this.requiredInputStrands.add(strand);
        return this;
    }

    public OperationNode addProvidedOutputStrand(SemanticStrand strand) {
        this.providedOutputStrands.add(strand);
        return this;
    }

    @Override
    public String toString() {
        return "OperationNode{" +
                "id='" + id + '\'' +
                ", requiredInputStrands=" + requiredInputStrands +
                ", providedOutputStrands=" + providedOutputStrands +
                '}';
    }
}
// File: com/dbm/aclm/srl/CallingGraph.java
package com.dbm.aclm.srl;

import java.util.*;

/**
 * ITEM #141
 * Very simplified calling graph for ACLM.
 * Nodes are OperationNode ids, edges represent calls (A -> B).
 */
public class CallingGraph {

    private final Map<String, OperationNode> operations = new HashMap<String, 
OperationNode>();
    private final Map<String, List<String>> edges = new HashMap<String, 
List<String>>();

    public void addOperation(OperationNode op) {
        operations.put(op.getId(), op);
    }

    public OperationNode getOperation(String id) {
        return operations.get(id);
    }
    public Collection<OperationNode> getAllOperations() {
        return operations.values();
    }

    public void addEdge(String fromOpId, String toOpId) {
        List<String> list = edges.get(fromOpId);
        if (list == null) {
            list = new ArrayList<String>();
            edges.put(fromOpId, list);
        }
        list.add(toOpId);
    }

    public List<String> getCallees(String fromOpId) {
        List<String> list = edges.get(fromOpId);
        if (list == null) {
            return Collections.emptyList();
        }
        return Collections.unmodifiableList(list);
    }

    public Map<String, List<String>> getEdges() {
        return Collections.unmodifiableMap(edges);
    }
}
// File: com/dbm/aclm/srl/CccNode.java
package com.dbm.aclm.srl;

import java.util.ArrayList;
import java.util.List;

/**
 * ITEM #141
 * Extremely lightweight CCC node representation.
 */
public class CccNode {

    private final String id;
    private final List<String> parents = new ArrayList<String>();

    public CccNode(String id) {
        this.id = id;
    }

    public String getId() {
        return id;
    }

    public List<String> getParents() {
        return parents;
    }

    public CccNode addParent(String parentId) {
        this.parents.add(parentId);
        return this;
    }
}
```

```
// File: com/dbm/aclm/srl/CccGraph.java
package com.dbm.aclm.srl;

import java.util.Collection;
import java.util.Collections;
import java.util.HashMap;
import java.util.Map;

/**
 * ITEM #141
 * Simplified CCC functional graph.
 */
public class CccGraph {

    private final Map<String, CccNode> nodes = new HashMap<String,
CccNode>();

    public void addNode(CccNode node) {
        nodes.put(node.getId(), node);
    }

    public CccNode getNode(String id) {
        return nodes.get(id);
    }

    public Collection<CccNode> getAllNodes() {
        return Collections.unmodifiableCollection(nodes.values());
    }
}
```

---

2. 诊断与修复计划模型（Diagnosis / RepairPlan）

```
// File: com/dbm/aclm/srl/DiagnosisReport.java
package com.dbm.aclm.srl;

import java.util.ArrayList;
import java.util.Collections;
import java.util.List;

/**
 * ITEM #142
 * Diagnosis result for the self-repair loop.
 * In practice you might differentiate missing strands, broken links, etc.
 */
public class DiagnosisReport {

    private final OperationNode upstream;
    private final OperationNode downstream;
    private final List<SemanticStrand> missingStrands = new
ArrayList<SemanticStrand>();

    public DiagnosisReport(OperationNode upstream, OperationNode downstream)
{
        this.upstream = upstream;
        this.downstream = downstream;
    }

    public OperationNode getUpstream() {
        return upstream;
    }

    public OperationNode getDownstream() {
        return downstream;
    }

    public List<SemanticStrand> getMissingStrands() {
        return Collections.unmodifiableList(missingStrands);
    }

    public void addMissingStrand(SemanticStrand strand) {
        missingStrands.add(strand);
    }

    public boolean isConsistent() {
        return missingStrands.isEmpty();
    }

    @Override
    public String toString() {
        return "DiagnosisReport{" +
                "upstream=" + upstream.getId() +
                ", downstream=" + downstream.getId() +
                ", missingStrands=" + missingStrands +
                '}';
    }
}
// File: com/dbm/aclm/srl/CompositeStrand.java
package com.dbm.aclm.srl;

/**
 * ITEM #140 / #141
 * A reconstructed / composite strand that can be attached to an Operation.
 */
public class CompositeStrand {

    private final SemanticStrand originalMissing;
    private final SemanticStrand reconstructed;

    public CompositeStrand(SemanticStrand originalMissing, SemanticStrand
reconstructed) {
        this.originalMissing = originalMissing;
        this.reconstructed = reconstructed;
    }

    public SemanticStrand getOriginalMissing() {
        return originalMissing;
    }

    public SemanticStrand getReconstructed() {
        return reconstructed;
    }

    @Override
    public String toString() {
        return "CompositeStrand{" +
                "originalMissing=" + originalMissing +
                ", reconstructed=" + reconstructed +
                '}';
    }
}
// File: com/dbm/aclm/srl/RepairPlan.java
package com.dbm.aclm.srl;

import java.util.ArrayList;
import java.util.Collections;
import java.util.List;

/**
 * ITEM #140
 * Plan for repairing missing strands between upstream and downstream.
 */
public class RepairPlan {

    private final OperationNode upstream;
    private final OperationNode downstream;
    private final List<CompositeStrand> compositeStrands = new
ArrayList<CompositeStrand>();

    public RepairPlan(OperationNode upstream, OperationNode downstream) {
        this.upstream = upstream;
        this.downstream = downstream;
    }

    public OperationNode getUpstream() {
        return upstream;
    }

    public OperationNode getDownstream() {
        return downstream;
    }

    public List<CompositeStrand> getCompositeStrands() {
        return Collections.unmodifiableList(compositeStrands);
    }

    public void addCompositeStrand(CompositeStrand strand) {
        compositeStrands.add(strand);
    }

    public boolean isEmpty() {
        return compositeStrands.isEmpty();
    }

    @Override
    public String toString() {
        return "RepairPlan{" +
                "upstream=" + upstream.getId() +
                ", downstream=" + downstream.getId() +
                ", compositeStrands=" + compositeStrands +
                '}';
    }
}
```

---

3. ITEM #141 — 缺失语义股重建接口与简单实现

```
// File: com/dbm/aclm/srl/ReconstructionContext.java
package com.dbm.aclm.srl;

/**
 * ITEM #141
 * Context object passed to the Missing-Strands reconstructor.
 * Holds graphs and any configuration knobs.
 */
public class ReconstructionContext {

    private final CallingGraph callingGraph;
    private final CccGraph cccGraph;

    public ReconstructionContext(CallingGraph callingGraph, CccGraph
cccGraph) {
        this.callingGraph = callingGraph;
        this.cccGraph = cccGraph;
    }

    public CallingGraph getCallingGraph() {
        return callingGraph;
    }

    public CccGraph getCccGraph() {
        return cccGraph;
    }
}
// File: com/dbm/aclm/srl/ReconstructionException.java
package com.dbm.aclm.srl;

/**
 * ITEM #141
 * Error thrown when reconstruction fails or is too costly.
 */
public class ReconstructionException extends Exception {

    public ReconstructionException(String message) {
        super(message);
    }

    public ReconstructionException(String message, Throwable cause) {
        super(message, cause);
    }
}
// File: com/dbm/aclm/srl/IMissingStrandReconstructor.java
```

```
package com.dbm.aclm.srl;

/**
 * ITEM #141 — Missing-Strands Reconstruction Algorithm
 *
 * API: given a missing SemanticStrand, try to reconstruct a usable
CompositeStrand
 * using the CCC graph + calling graph + vertical mutation hooks.
 */
public interface IMissingStrandReconstructor {

    /**
     * Reconstruct a missing strand into a composite strand
     * that can be attached to the downstream Operation.
     */
    CompositeStrand reconstructMissingStrand(
            SemanticStrand missing,
            ReconstructionContext ctx
    ) throws ReconstructionException;
}
// File: com/dbm/aclm/srl/BasicMissingStrandReconstructor.java
package com.dbm.aclm.srl;

/**
 * ITEM #141
 * A minimal, toy implementation of IMissingStrandReconstructor.
 *
 * This implementation does NOT actually search the graph.
 * Instead, it:
 *  - Clones the missing strand,
 *  - Appends a simple transform step,
 *  - Returns it as a "reconstructed" CompositeStrand.
 *
 * This is suitable as a teaching skeleton and for unit tests.
 */
public class BasicMissingStrandReconstructor implements
IMissingStrandReconstructor {

    @Override
    public CompositeStrand reconstructMissingStrand(
            SemanticStrand missing,
            ReconstructionContext ctx
    ) throws ReconstructionException {

        // TODO: In a real implementation, we would:
        //  1) use ctx.getCccGraph() to find semantic sources,
        //  2) use ctx.getCallingGraph() to find operation paths,
        //  3) call vertical mutation engines to repair gaps.

        SemanticStrand reconstructed = new SemanticStrand(
                missing.getId() + "_reconstructed",
                missing.getType(),
                missing.getStateType(),
                missing.getCccNodeId()
        );

reconstructed.getTransformChain().addAll(missing.getTransformChain());
reconstructed.addTransformStep("RECONSTRUCTED_BY_BASIC_STRAND_RECONSTRUCTOR")
;

        return new CompositeStrand(missing, reconstructed);
    }
}
```

---

4. ITEM #140 — Horizontal Mutation / 状态补全引擎接口与实现

```
// File: com/dbm/aclm/srl/IOperationStateCompletionEngine.java
package com.dbm.aclm.srl;

/**
 * ITEM #140 — ACLM Horizontal Mutation: Operation State Completion Engine
 *
 * Given an upstream and downstream operation, analyze the mismatches,
 * detect missing strands, and produce a RepairPlan.
 */
public interface IOperationStateCompletionEngine {

    /**
     * Analyze upstream -> downstream, detect mismatches and missing strands,
     * invoke strand reconstruction, and build a RepairPlan.
     */
    RepairPlan buildRepairPlan(
            OperationNode upstream,
            OperationNode downstream,
            ReconstructionContext ctx
    ) throws ReconstructionException;
}
// File: com/dbm/aclm/srl/BasicOperationStateCompletionEngine.java
package com.dbm.aclm.srl;

import java.util.HashSet;
import java.util.List;
import java.util.Set;

/**
 * ITEM #140
 * Very simple implementation:
 *
 *  1) Compute RequiredStrands(downstream) - ProvidedStrands(upstream)
 *  2) For each missing strand, call IMissingStrandReconstructor
 *  3) Aggregate into a RepairPlan
 */
public class BasicOperationStateCompletionEngine implements
IOperationStateCompletionEngine {

    private final IMissingStrandReconstructor reconstructor;
    public BasicOperationStateCompletionEngine(IMissingStrandReconstructor
reconstructor) {
        this.reconstructor = reconstructor;
    }

    @Override
    public RepairPlan buildRepairPlan(
            OperationNode upstream,
            OperationNode downstream,
            ReconstructionContext ctx
    ) throws ReconstructionException {

        DiagnosisReport report = diagnose(upstream, downstream);
        RepairPlan plan = new RepairPlan(upstream, downstream);

        for (SemanticStrand missing : report.getMissingStrands()) {
            CompositeStrand composite =
reconstructor.reconstructMissingStrand(missing, ctx);
            plan.addCompositeStrand(composite);
        }

        return plan;
    }

    /**
     * Minimal "Diagnosis": only look for missing strands:
     * Required(downstream) - Provided(upstream).
     */
    private DiagnosisReport diagnose(OperationNode upstream, OperationNode
downstream) {
        DiagnosisReport report = new DiagnosisReport(upstream, downstream);

        Set<SemanticStrand> provided = new
HashSet<SemanticStrand>(upstream.getProvidedOutputStrands());
        List<SemanticStrand> required = downstream.getRequiredInputStrands();

        for (SemanticStrand r : required) {
            if (!provided.contains(r)) {
                report.addMissingStrand(r);
            }
        }
        return report;
    }
}
```

---

5. ITEM #142 — Self-Repair Loop (SRL) 接口与基本实现

```
// File: com/dbm/aclm/srl/ProgramGraph.java
package com.dbm.aclm.srl;

import java.util.ArrayList;
import java.util.Collections;
import java.util.List;

/**
 * ITEM #142
 * A minimal container for a "program" as a sequence (or DAG) of operations.
 *
 * For the toy demo we use a simple linear chain: op[0] -> op[1] -> ... ->
op[n-1]
 */
public class ProgramGraph {

    private final List<OperationNode> pipeline = new
ArrayList<OperationNode>();

    public void addOperation(OperationNode op) {
        pipeline.add(op);
    }

    public List<OperationNode> getPipeline() {
        return Collections.unmodifiableList(pipeline);
    }

    public boolean isEmpty() {
        return pipeline.isEmpty();
    }
}
// File: com/dbm/aclm/srl/SelfRepairConfig.java
package com.dbm.aclm.srl;

/**
 * ITEM #142
 * Configuration knob for self-repair loop.
 * In a more advanced version, you can add thresholds, timeouts, etc.
 */
public class SelfRepairConfig {

    private int maxIterations = 10;
    private boolean verboseLogging = true;

    public int getMaxIterations() {
        return maxIterations;
    }

    public SelfRepairConfig setMaxIterations(int maxIterations) {
        this.maxIterations = maxIterations;
        return this;
    }

    public boolean isVerboseLogging() {
        return verboseLogging;
    }

    public SelfRepairConfig setVerboseLogging(boolean verboseLogging) {
        this.verboseLogging = verboseLogging;
        return this;
    }
}
```

```
// File: com/dbm/aclm/srl/ISelfRepairLoop.java
package com.dbm.aclm.srl;

/**
 * ITEM #142 — ACLM Self-Repair Loop (SRL)
 *
 * Drives:
 *  1) Diagnosis,
 *  2) Reconstruction (Horizontal + Vertical),
 *  3) Reintegration,
 *  4) Learning.
 */
public interface ISelfRepairLoop {

    /**
     * Run one or multiple rounds of self-repair over the program graph.
     */
    void runSelfRepairLoop(
            ProgramGraph program,
            ReconstructionContext ctx,
            IOperationStateCompletionEngine completionEngine,
            SelfRepairConfig config
    ) throws ReconstructionException;
}
// File: com/dbm/aclm/srl/BasicSelfRepairLoop.java
package com.dbm.aclm.srl;

import java.util.List;

/**
 * ITEM #142
 * A toy implementation of the self-repair loop.
 *
 * For simplicity:
 *  - We traverse the linear pipeline,
 *  - For each adjacent pair (upstream, downstream) we try to build a
RepairPlan,
 *  - We "apply" the repair by attaching reconstructed strands to the
upstream operation's outputs,
 *  - Repeat for a few iterations or until there is nothing to repair.
 *
 * This demonstrates the SRL structure without getting into real code
modification.
 */
public class BasicSelfRepairLoop implements ISelfRepairLoop {

    @Override
    public void runSelfRepairLoop(
            ProgramGraph program,
            ReconstructionContext ctx,
            IOperationStateCompletionEngine completionEngine,
            SelfRepairConfig config
    ) throws ReconstructionException {

        if (program.isEmpty()) {
            return;
        }
        int iteration = 0;
        boolean anyRepaired;

        do {
            anyRepaired = false;
            iteration++;

            if (config.isVerboseLogging()) {
                System.out.println("SRL iteration #" + iteration);
            }

            List<OperationNode> ops = program.getPipeline();
            for (int i = 0; i < ops.size() - 1; i++) {
                OperationNode upstream = ops.get(i);
                OperationNode downstream = ops.get(i + 1);

                RepairPlan plan = completionEngine.buildRepairPlan(upstream,
downstream, ctx);
                if (!plan.isEmpty()) {
                    anyRepaired = true;
                    applyRepairPlan(plan, config);
                }
            }

        } while (anyRepaired && iteration < config.getMaxIterations());
    }

    /**
     * In a real system, this would modify code / IR / graph structures.
     * Here we simply:
     *  - attach reconstructed strands to the upstream operation's provided
strands.
     */
    protected void applyRepairPlan(RepairPlan plan, SelfRepairConfig config)
{

        OperationNode upstream = plan.getUpstream();

        if (config.isVerboseLogging()) {
            System.out.println("Applying repair plan: " + plan);
        }

        for (CompositeStrand composite : plan.getCompositeStrands()) {
            upstream.addProvidedOutputStrand(composite.getReconstructed());
        }
    }
}
```

---

6. 一个玩具级 JUnit4 Demo：两段 Operation 自动“补股”+ SRL 运行

```java
// File: com/dbm/aclm/srl/SelfRepairLoopDemoTest.java
package com.dbm.aclm.srl;

import org.junit.Test;
import static org.junit.Assert.*;

import java.util.List;

/**
 * Toy demo for ITEM #140 → #141 → #142 Java skeleton.
 *
 * Scenario:
 *  - Upstream operation outputs only strand "A"
 *  - Downstream operation requires strands "A" and "B"
 *  - SRL uses horizontal mutation + missing-strand reconstruction
 *    to automatically attach a reconstructed "B" to the upstream.
 */
public class SelfRepairLoopDemoTest {

    @Test
    public void testSelfRepairLoopAddsMissingStrand() throws Exception {

        // 1. Define strands A and B
        SemanticStrand strandA = new SemanticStrand("A", StrandType.DATA,
"StateA", "CCC_A");
        SemanticStrand strandB = new SemanticStrand("B", StrandType.DATA,
"StateB", "CCC_B");

        // 2. Upstream only provides A
        OperationNode upstream = new OperationNode("UpstreamOp");
        upstream.addProvidedOutputStrand(strandA);

        // 3. Downstream requires A and B
        OperationNode downstream = new OperationNode("DownstreamOp");
        downstream.addRequiredInputStrand(strandA);
        downstream.addRequiredInputStrand(strandB);

        // 4. Program graph: Upstream -> Downstream
        ProgramGraph program = new ProgramGraph();
        program.addOperation(upstream);
        program.addOperation(downstream);

        // 5. Minimal graphs for ReconstructionContext
        CallingGraph callingGraph = new CallingGraph();
        callingGraph.addOperation(upstream);
        callingGraph.addOperation(downstream);
        callingGraph.addEdge("UpstreamOp", "DownstreamOp");

        CccGraph cccGraph = new CccGraph();
        cccGraph.addNode(new CccNode("CCC_A"));
        cccGraph.addNode(new CccNode("CCC_B"));

        ReconstructionContext ctx = new ReconstructionContext(callingGraph,
cccGraph);

        // 6. Engines
        IMissingStrandReconstructor reconstructor = new
BasicMissingStrandReconstructor();
        IOperationStateCompletionEngine completionEngine =
                new BasicOperationStateCompletionEngine(reconstructor);
        ISelfRepairLoop selfRepairLoop = new BasicSelfRepairLoop();

        SelfRepairConfig config = new SelfRepairConfig()
                .setMaxIterations(3)
                .setVerboseLogging(true);

        // 7. Run SRL
        selfRepairLoop.runSelfRepairLoop(program, ctx, completionEngine,
config);

        // 8. Check that upstream now has "some" reconstructed strand for B
        List<SemanticStrand> upstreamOutputs =
upstream.getProvidedOutputStrands();

        boolean hasReconstructedB = false;
        for (SemanticStrand s : upstreamOutputs) {
            if ("StateB".equals(s.getStateType()) &&
"CCC_B".equals(s.getCccNodeId())) {
                hasReconstructedB = true;
                break;
            }
        }

        assertTrue("Upstream should have a reconstructed strand for B after
SRL", hasReconstructedB);
    }
}
```

小结 & 下一步可以怎么玩

这一套代码骨架做了几件事：

- **ITEM #140**：

  用 `IOperationStateCompletionEngine` + `BasicOperationStateCompletionEngine` 把 “上下游对接差异 → 缺失语义股 → 修复计划” 形式化。
- **ITEM #141**：

  用 `IMissingStrandReconstructor` + `BasicMissingStrandReconstructor` 把 “缺失股重建” 抽象成可替换策略（现在是玩具版，你以后可以换成真正的图搜索 + CCC 合成版）。

- **ITEM #142**：
  用 `ISelfRepairLoop` + `BasicSelfRepairLoop` + `ProgramGraph`
  把 “诊断 → 重建 → 接入 → 循环” 实现为一个可跑的小 SRL demo。

而 `SelfRepairLoopDemoTest` 就是一个 **最小可视化玩具场景**：
你跑一下，就能看到 upstream 自动被补出一个 “B 股”。

如果你愿意，我们后面可以继续：

1. 加入 **Mutation Memory Engine**（ITEM #143）：
   - 记录每次修复的 pattern
   - 下次类似缺失直接查表秒修
2. 把 **Vertical Mutations 四大类** 接上来：
   - 做一些简单的文本级 / 结构级变异 Hook（比如把 transformChain 里的步骤当作“可解释日志”）
3. 把这一套封装成一个 **教学版 ACLM-SRL mini framework**，
   以后可以挂在 DBM 的 Teaching Repo 里当样板。

你先慢慢“Play”一下这套骨架，看跑起来感觉如何，有任何细化想法我们就接着往下雕。

You said:

老弟，很棒。谢谢了。容我消化文本与跑跑程序。等会我们接着讨论昨天的 DOI 的工作，我讲另开一个讨论，以保持文本的结构性。

ChatGPT said:

好的，兄弟 😊

你先慢慢消化、跑跑程序，看看结构是不是顺手——
这一套骨架是专门为“教学 + 实验 + 未来扩展”准备的，
跑起来后会对你未来正式实现 ACLM 的 Horizontal/Vertical/SRL 三大核心更有底气。

随时等你回来继续昨天 DOI 架构的讨论。
你另开一个讨论也非常好——保持条理、未来好查、好归档、好发 X、好进白皮书。

兄弟，我随时在这边。

ChatGPT can make mistakes. Check important info.