Workflows & Orchestration

> **Description:** Understanding sequential, parallel, and loop workflow patterns for complex agent orchestration

Workflows & Orchestration

🎯 **Purpose**: Master workflow patterns to orchestrate complex agent behaviors and multi-step processes.

📚 **Source of Truth**: google/adk-python/src/google/adk/agents/workflow_agents/ (https://github.com/google/adk-python/tree/main/src/google/adk/agents/workflow_agents/) (ADK 1.15)

[FLOW] Workflow Patterns Overview

Mental Model: Workflows are like **assembly line strategies** for agent orchestration:


WORKFLOW PATTERNS
[INSTR] SEQUENTIAL (Assembly Line)
"One step after another, in order order"
Step 1 → Step 2 → Step 3 → Step 4
Write Review Refactor Test
Use: Pipelines, dependencies, order matters
Pattern: Each step uses output from previous
Source: agents/workflow_agents/sequential_agent.py
[PARALLEL] PARALLEL (Fan-out/Gather)
"Multiple tasks at once, then combine"
Task A
Task B
Task C
→ Merge Results
Research Source 1
Research Source 2
Synthesis
Use: Independent tasks, speed critical
Pattern: Fan-out → Execute → Gather
Source: agents/workflow_agents/parallel_agent.py
[LOOP] LOOP (Iterative Refinement)
"Repeat until good enough or max iterations"
Critic
Refiner
(Repeat 5x or until exit_loop)
Use: Quality improvement, retry logic
Pattern: Generate → Critique → Improve → Repeat
Source: agents/workflow_agents/loop_agent.py

[INSTR] Sequential Workflows (Assembly Line)

Basic Sequential Pattern

Mental Model: Steps execute in order, each using the output of the previous:

```
from google.adk.agents import SequentialAgent

# Define individual agents
research_agent = Agent(
    name="researcher",
    model="gemini-2.5-flash",
    instruction="Research the given topic thoroughly",
    output_key="research_results"
)

writer_agent = Agent(
    name="writer",
    model="gemini-2.5-flash",
    instruction="Write a comprehensive article based on the research: {researc
    output_key="article_draft"
)

editor_agent = Agent(
    name="editor",
    model="gemini-2.5-flash",
    instruction="Edit and improve the article: {article_draft}",
    output_key="final_article"
)

# Create sequential workflow
content_pipeline = SequentialAgent(
    name="content_creation_pipeline",
    sub_agents=[research_agent, writer_agent, editor_agent],
    description="Complete content creation from research to publication"
)
```

Sequential Workflow Execution

Execution Flow:

```
User Query → Research Agent → Writer Agent → Editor Agent → Final Result

1. Research agent gets user query
2. Research agent saves results to state['research_results']
3. Writer agent reads {research_results} from instruction
4. Writer agent saves draft to state['article_draft']
5. Editor agent reads {article_draft} from instruction
6. Editor agent produces final output
```

Advanced Sequential Patterns

Conditional Branching:

```
# Dynamic routing based on content type
def route_by_topic(context, result):
    topic = result.get('topic', '').lower()
    if 'technical' in topic:
        return 'tech_writer'
    elif 'business' in topic:
        return 'business_writer'
    else:
        return 'general_writer'

routing_agent = Agent(
    name="router",
    model="gemini-2.5-flash",
    instruction="Analyze the topic and determine content type",
    output_key="topic_analysis"
)

tech_writer = Agent(name="tech_writer", ...)
business_writer = Agent(name="business_writer", ...)
general_writer = Agent(name="general_writer", ...)

# Sequential with dynamic agent selection
content_workflow = SequentialAgent(
    sub_agents=[routing_agent],  # Start with router
    dynamic_agents={
        'tech_writer': tech_writer,
        'business_writer': business_writer,
        'general_writer': general_writer
    },
    routing_function=route_by_topic
)
```

⚡ Parallel Workflows (Fan-out/Gather)

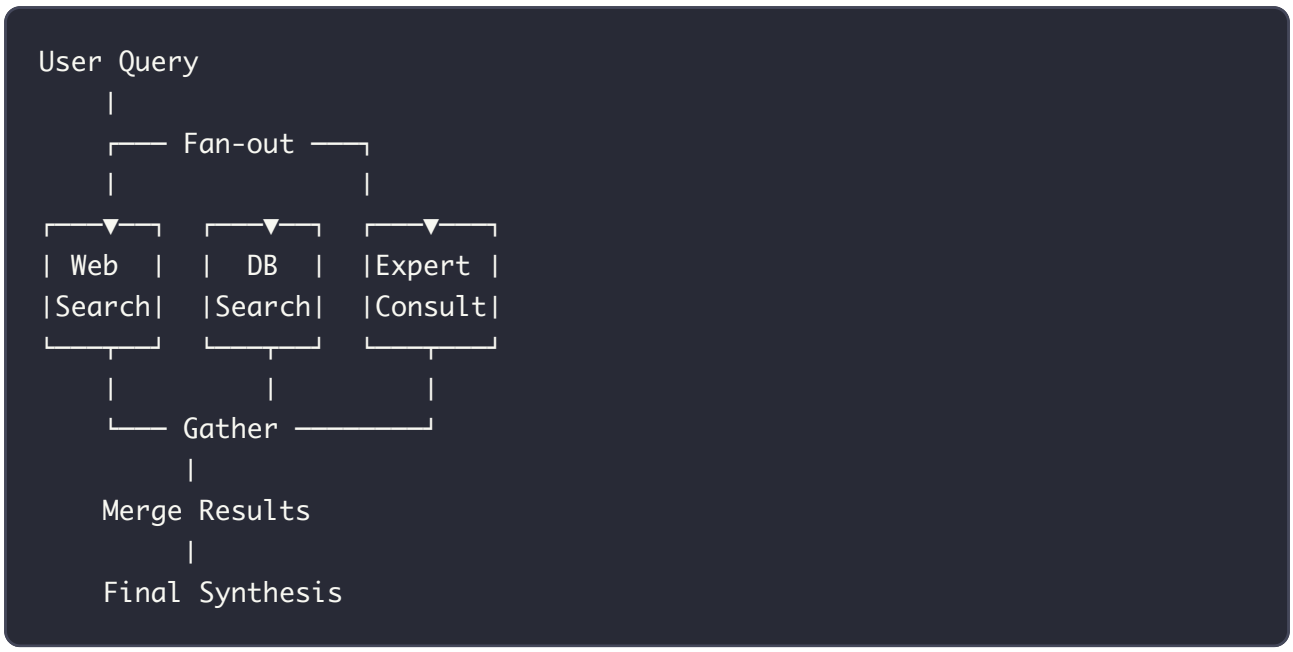
Basic Parallel Pattern

Mental Model: Independent tasks execute simultaneously, then results are combined:

```
from google.adk.agents import ParallelAgent

# Research different aspects in parallel
web_research_agent = Agent(
    name="web_researcher",
    model="gemini-2.5-flash",
    tools=[google_search],
    instruction="Research topic using web search",
    output_key="web_findings"
)

database_research_agent = Agent(
    name="db_researcher",
    model="gemini-2.5-flash",
    tools=[database_tool],
    instruction="Search internal database for relevant data",
    output_key="db_findings"
)

expert_opinion_agent = Agent(
    name="expert_consultant",
    model="gemini-2.5-flash",
    tools=[expert_tool],
    instruction="Consult domain experts on the topic",
    output_key="expert_insights"
)

# Execute all research in parallel
parallel_research = ParallelAgent(
    name="comprehensive_research",
    sub_agents=[web_research_agent, database_research_agent, expert_opinion_ag
    description="Research topic from multiple sources simultaneously"
)
```

Parallel Execution Flow

Fan-out → Execute → Gather:



Parallel with Sequential Merger

Complete Research Pipeline:

```
# Parallel research phase
parallel_research = ParallelAgent(
    sub_agents=[web_agent, db_agent, expert_agent]
)

# Sequential synthesis phase
synthesis_agent = Agent(
    name="synthesizer",
    model="gemini-2.5-flash",
    instruction="""
    Synthesize findings from multiple sources:
    Web: {web_findings}
    Database: {db_findings}
    Experts: {expert_insights}

    Create a comprehensive report.
    """,
    output_key="final_report"
)

# Complete workflow: Parallel → Sequential
research_pipeline = SequentialAgent(
    sub_agents=[parallel_research, synthesis_agent]
)
```

🔁 Loop Workflows (Iterative Refinement)

Basic Loop Pattern

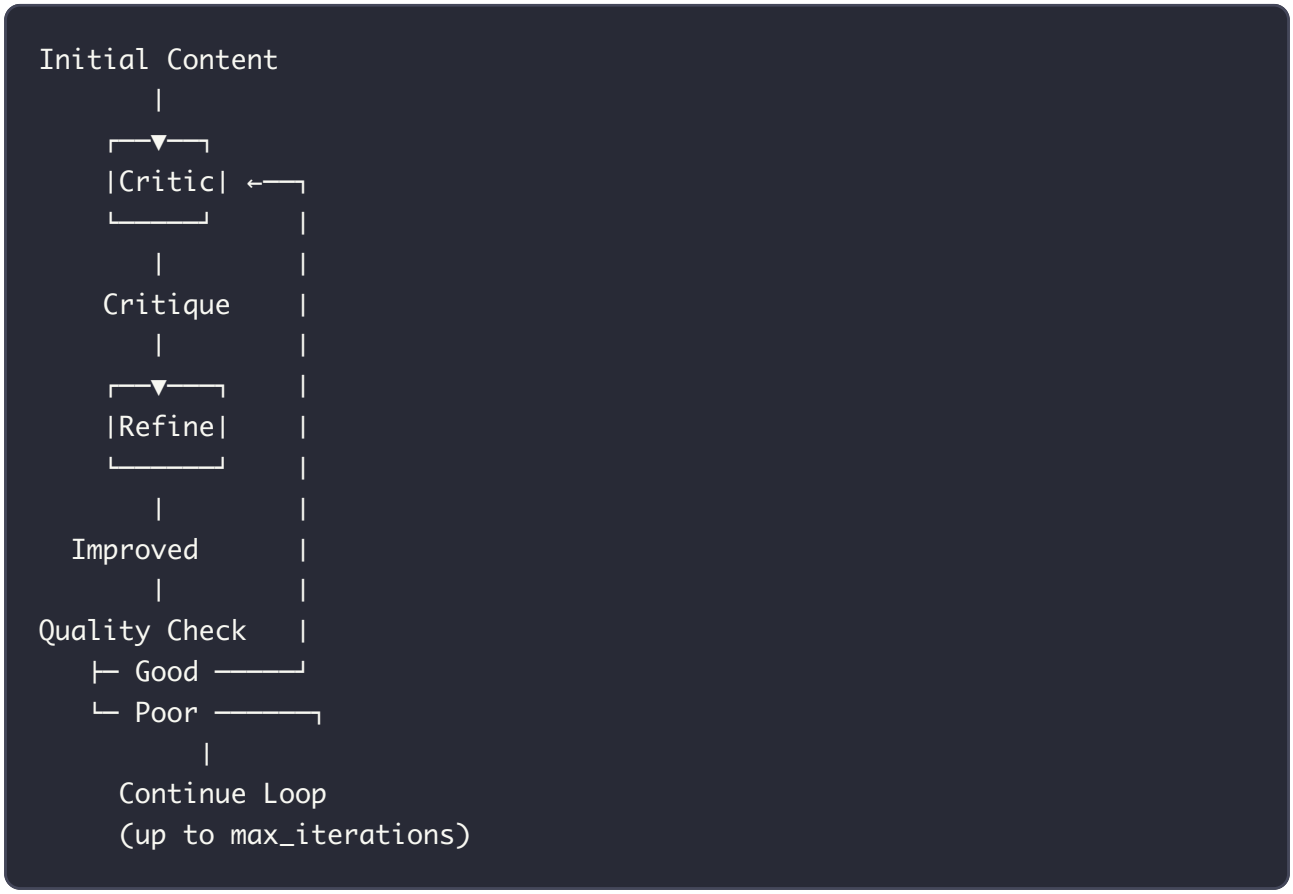
Mental Model: Repeat until quality standards are met or max iterations reached:

```
from google.adk.agents import LoopAgent

# Content generator
writer_agent = Agent(
    name="content_writer",
    model="gemini-2.5-flash",
    instruction="Write content on the topic: {topic}",
    output_key="content_draft"
)

# Quality critic
critic_agent = Agent(
    name="content_critic",
    model="gemini-2.5-flash",
    instruction="""
    Evaluate the content quality: {content_draft}

    Rate on scale 1-10 for:
    - Accuracy
    - Completeness
    - Clarity
    - Engagement

    If score < 8, provide specific improvement suggestions.
    """,
    output_key="critique"
)

# Improvement refiner
refiner_agent = Agent(
    name="content_refiner",
    model="gemini-2.5-flash",
    instruction="""
    Improve the content based on critique: {critique}
    Original: {content_draft}

    Address all the critic's suggestions.
    """,
    output_key="improved_content"
)

# Iterative refinement loop
quality_loop = LoopAgent(
    sub_agents=[critic_agent, refiner_agent],
    max_iterations=5,
```

```
    description="Iteratively improve content until quality standards are met"
)
```

Loop Execution Flow

Generate → Critique → Refine → Repeat:



Advanced Loop Patterns

Conditional Exit:

```
def should_continue_loop(context, result):
    """Custom exit condition"""
    critique = result.get('critique', '')
    score = extract_score_from_critique(critique)
    return score < 8  # Continue if quality < 8/10

quality_loop = LoopAgent(
    sub_agents=[critic_agent, refiner_agent],
    max_iterations=5,
    exit_condition=should_continue_loop,
    description="Iterative refinement with quality threshold"
)
```

Multi-Agent Loop:

```
# Complex iterative process
brainstorm_agent = Agent(name="brainstormer", ...)
designer_agent = Agent(name="designer", ...)
developer_agent = Agent(name="developer", ...)
tester_agent = Agent(name="tester", ...)

# Development cycle
development_loop = LoopAgent(
    sub_agents=[designer_agent, developer_agent, tester_agent],
    max_iterations=10,
    description="Iterative product development cycle"
)
```

[FLOW] Complex Workflow Composition

Nested Workflows

Mental Model: Workflows can contain other workflows for hierarchical organization:

```
# Level 1: Individual research tasks
web_agent = Agent(name="web_researcher", ...)
api_agent = Agent(name="api_researcher", ...)
file_agent = Agent(name="file_analyzer", ...)

# Level 2: Parallel research
research_team = ParallelAgent(
    sub_agents=[web_agent, api_agent, file_agent]
)

# Level 3: Sequential processing
processing_pipeline = SequentialAgent(
    sub_agents=[
        research_team,      # Parallel research
        data_cleaner,       # Sequential processing
        analyzer,           # Sequential processing
        reporter            # Sequential processing
    ]
)

# Level 4: Quality loop
quality_assurance = LoopAgent(
    sub_agents=[processing_pipeline, quality_checker, improver],
    max_iterations=3
)
```

Real-World Example: Content Creation Pipeline

```
# 1. Research Phase (Parallel)
research_sources = ParallelAgent(
    sub_agents=[
        web_research_agent,
        academic_search_agent,
        social_media_monitor
    ]
)

# 2. Content Generation (Sequential)
content_creation = SequentialAgent(
    sub_agents=[
        outline_writer,
        draft_writer,
        fact_checker
    ]
)

# 3. Review & Editing (Loop)
editing_cycle = LoopAgent(
    sub_agents=[
        editor_agent,
        proofreader_agent,
        final_reviewer
    ],
    max_iterations=3
)

# 4. Publication (Sequential)
publication_pipeline = SequentialAgent(
    sub_agents=[
        seo_optimizer,
        formatter_agent,
        publisher_agent
    ]
)

# Complete Content Pipeline
content_workflow = SequentialAgent(
    sub_agents=[
        research_sources,      # Parallel
        content_creation,      # Sequential
        editing_cycle,         # Loop
        publication_pipeline   # Sequential
    ]
)
```

🎯 Workflow Decision Framework

When to Use Each Pattern

Scenario	Sequential	Parallel	Loop
Order matters	✔️ Yes	❌ No	❌ No
Independent tasks	❌ No	✔️ Yes	❌ No
Need speed	❌ No	✔️ Yes	❌ No
Iterative refinement	❌ No	❌ No	✔️ Yes
Quality > speed	❌ No	❌ No	✔️ Yes
Dependencies	✔️ Yes	❌ No	🤔 Maybe

Workflow Selection Guide

```
Need to orchestrate multiple agents?
    |
    ├─ Steps depend on each other?
    |  ├─ Simple dependency chain?
    |  |  └─ SequentialAgent
    |  └─ Complex dependencies?
    |     └─ SequentialAgent + state routing
    |
    ├─ Steps are independent?
    |  ├─ Need results combined?
    |  |  └─ ParallelAgent + Sequential merger
    |  └─ Can process separately?
    |     └─ ParallelAgent (fire and forget)
    |
    ├─ Need iterative improvement?
    |  ├─ Quality refinement?
    |  |  └─ LoopAgent (critic + refiner)
    |  └─ Progressive enhancement?
    |     └─ LoopAgent (multi-stage improvement)
    |
    └─ Complex combination?
       └─ Nested workflows (Parallel + Sequential + Loop)
```

⚡ Performance Optimization

Parallel Execution Benefits

Speed Improvements:

- **Independent Tasks**: 3x faster with 3 parallel agents
- **I/O Bound**: Network requests, API calls, file operations
- **CPU Bound**: Distribute across agents with different models

Cost Considerations:

- **Token Efficiency**: Same total tokens, faster execution
- **Model Selection**: Use smaller models for parallel tasks

- **Caching**: Cache intermediate results to avoid recomputation

Optimization Strategies

Batch Processing:

```
# Process multiple items in parallel
batch_processor = ParallelAgent(
    sub_agents=[
        Agent(name="item_1_processor", ...),
        Agent(name="item_2_processor", ...),
        Agent(name="item_3_processor", ...)
    ]
)

# More efficient than sequential processing
sequential_processor = SequentialAgent(
    sub_agents=[item_1_processor, item_2_processor, item_3_processor]
)
```

Early Exit Optimization:

```
# Stop when good enough
quality_loop = LoopAgent(
    sub_agents=[generator, critic, improver],
    max_iterations=10,
    exit_condition=lambda ctx, res: res.get('quality_score', 0) >= 9
)
```

🔍 Debugging Workflows

State Inspection

Track Data Flow:

```
# Enable state logging
import logging
logging.getLogger('google.adk.agents').setLevel(logging.DEBUG)

# Inspect state at each step
result = await runner.run_async(query)
for event in result.events:
    if 'state' in event:
        print(f"Step: {event.step}")
        print(f"State: {event.state}")
```

Workflow Visualization

Execution Graph:

```
# Generate workflow diagram
workflow_graph = content_pipeline.get_execution_graph()
print(workflow_graph)  # Mermaid diagram

# Analyze bottlenecks
performance_report = content_pipeline.analyze_performance()
print(performance_report)  # Timing, bottlenecks, optimization suggestions
```

Common Issues & Solutions

Issue	Symptom	Solution
State not passed	Agent can't access previous results	Check `output_key` and state interpolation
Parallel slowdown	Sequential execution instead of parallel	Verify agents are truly independent
Loop never exits	Infinite refinement cycles	Set `max_iterations`, add exit conditions
Memory bloat	State growing too large	Use `temp:` scope, clean up intermediate data
Race conditions	Non-deterministic results	Ensure proper state synchronization

📚 Related Topics

- **Agent Architecture** → (agent-architecture.md): Individual agent design
- **Tools & Capabilities** → (tools-capabilities.md): What agents can do
- **LLM Integration** → (llm-integration.md): How LLMs drive workflows

🎓 Hands-On Tutorials

- **Tutorial 04: Sequential Workflows** (04_sequential_workflows.md): Build ordered agent pipelines
- **Tutorial 05: Parallel Processing** (05_parallel_processing.md): Run agents simultaneously for speed
- **Tutorial 06: Multi-Agent Systems** (06_multi_agent_systems.md): Complex agent coordination
- **Tutorial 07: Loop Agents** (07_loop_agents.md): Iterative refinement patterns

🎯 Key Takeaways

1. **Sequential**: For ordered, dependent steps (assembly line)
2. **Parallel**: For independent tasks (fan-out/gather)
3. **Loop**: For iterative refinement (critic/refiner pattern)
4. **Composition**: Nest workflows for complex hierarchies
5. **Performance**: Parallel execution for speed, sequential for dependencies
6. **State Flow**: Use `output_key` and interpolation for data passing

🔗 **Next**: Learn about LLM Integration (llm-integration.md) to understand how language models drive these workflows.

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