2025-11-01

section 0

[2em] **Part Overview · Duration:**

Beginner-Friendly Visual Study Guide

subsection 0.0 What You'll Learn

- **MCP Architecture**: 12 specialized servers (filesystem, github, pytest, pandas, etc.)
- **Auto-trigger Strategy**: Keyword-based orchestration (NO user confirmation needed)
- **Server Chaining**: Combine 3-5 MCPs for complete workflows
- **Integration**: .mcp.json configuration and debugging workflows

subsection 0.0 Why This Matters

Problem: Manual tool selection slows AI workflows (e.g., "Should I use filesystem or grep?").

Solution: MCPs auto-trigger based on task keywords (data analysis -> pandas-mcp, testing -> pytest-mcp, UI -> puppeteer).

Impact: Phase 5 research (11 tasks) leveraged 8/12 MCPs automatically, reducing manual tool selection by 70%.

section 0 The 12 MCP Servers

subsection 0.0 Core Servers (4)

enumi**filesystem**: File operations (read, write, list, search)

0. enumi**github**: Issues, PRs, checks, releases
0. enumi**sequential-thinking**: Planning, debugging, reasoning
0. enumi**puppeteer**: UI testing, browser automation

subsection 0.0 Development Servers (4)

0. enumi**pytest-mcp**: Test debugging, coverage analysis
0. enumi**git-mcp**: Advanced Git operations (rebase, cherry-pick, blame)
0. enumi**mcp-analyzer**: Code quality, linting, static analysis
0. enumi**mcp-debugger**: API testing, HTTP requests

subsection 0.0 Data Science Servers (3)

0. enumi**sqlite-mcp**: PSO optimization database queries
0. enumi**pandas-mcp**: Data analysis, CSV/JSON processing
0. enumi**numpy-mcp**: Numerical compute, matrix operations

subsection 0.0 Audit Server (1)

0. enumi**lighthouse-mcp**: Accessibility audits (WCAG compliance)

section 0 Auto-trigger Keywords

subsection 0.0 Filesystem MCP

Triggers: "read file", "list directory", "search files", "find *.py"

```
lstnumber# User: "Read all controller files"
lstnumber# AI auto-triggers: filesystem.list("src/controllers/")
lstnumber
lstnumber# User: "Find all test files"
lstnumber# AI auto-triggers: filesystem.search("test_*.py")
```

subsection 0.0 GitHub MCP

Triggers: "create PR", "list issues", "check CI status", "release notes"

```
lstnumber# User: "Create PR for LT-7 paper"
lstnumber# AI auto-triggers: github.create_pr(title="feat: Add LT-7 research paper", ...)
lstnumber
lstnumber# User: "List open issues"
lstnumber# AI auto-triggers: github.list_issues(state="open")
```

subsection 0.0 Pytest MCP

Triggers: "run tests", "debug test failure", "coverage report"

```
lstnumber# User: "Why is test_classical_smc failing?"
lstnumber# AI auto-triggers:
    pytest_mcp.debug("tests/test_controllers/test_classical_smc.py")
lstnumber
lstnumber# User: "Show coverage for controllers"
lstnumber# AI auto-triggers: pytest_mcp.coverage("src/controllers/")
```

subsection 0.0 Pandas MCP

Triggers: "analyze CSV", "plot benchmark data", "merge datasets"

```
lstnumber# User: "Analyze PSO convergence data"
lstnumber# AI auto-triggers: pandas_mcp.read_csv("optimization_results/pso_results.csv")
lstnumber# AI auto-triggers: pandas_mcp.plot(df["cost"], title="PSO Convergence")
lstnumber
lstnumber# User: "Merge controller benchmarks"
lstnumber# AI auto-triggers: pandas_mcp.merge(df1, df2, on="controller_name")
```

section 0 Server Chaining Patterns

subsection 0.0 Pattern 1: Data Analysis Pipeline

Goal: Analyze PSO optimization results (CSV -> DataFrame -> Plot)

```
lstnumber# Chain: filesystem -> sqlite -> pandas
lstnumber1. filesystem.read("optimization_results/pso_results.csv")
lstnumber2. sqlite_mcp.query("SELECT * FROM optimizations WHERE cost < 0.1")
lstnumber3. pandas_mcp.analyze(df)
lstnumber4. pandas_mcp.plot(df["iteration"], df["cost"])
```

subsection 0.0 Pattern 2: Testing Workflow

Goal: Debug failing test, analyze coverage, fix issue

```
lstnumber# Chain: pytest-mcp -> puppeteer -> mcp-analyzer
lstnumber1. pytest_mcp.run("tests/test_controllers/")
lstnumber2. pytest_mcp.debug("test_classical_smc::test_convergence")
lstnumber3. puppeteer.screenshot("UI elements for manual inspection")
lstnumber4. mcp_analyzer.lint("src/controllers/classical_smc.py")
```

subsection 0.0 Pattern 3: Research Task Workflow

Goal: Implement LT-7 paper generation (planning -> code -> data -> doc)

```
lstnumber# Chain: sequential-thinking -> filesystem -> pandas -> github
lstnumber1. sequential_thinking.plan("LT-7 research paper structure")
lstnumber2. filesystem.create("academic/paper/publications/lt7_paper.tex")
lstnumber3. pandas_mcp.analyze("benchmarks/processed/comparative_study.csv")
lstnumber4. pandas_mcp.generate_figures(df, output="academic/paper/figures/")
lstnumber5. github.create_pr(title="feat: Add LT-7 research paper")
```

section 0 MCP Configuration

subsection 0.0 Configuration File Structure

File: `.mcp.json`

```
lstnumber{
lstnumber  "mcpServers": {
lstnumber    "filesystem": {
lstnumber      "command": "npx",
lstnumber      "args": ["-y", "@modelcontextprotocol/server-filesystem",
          "D:/Projects/main"]
lstnumber    },
lstnumber    "github": {
lstnumber      "command": "npx",
lstnumber      "args": ["-y", "@modelcontextprotocol/server-github"],
lstnumber      "env": {
lstnumber        "GITHUB_PERSONAL_ACCESS_TOKEN": "ghp_xxxx"
lstnumber      }
lstnumber    },
lstnumber    "pytest-mcp": {
lstnumber      "command": "python",
lstnumber      "args": ["-m", "pytest_mcp"]
lstnumber    },
lstnumber    "pandas-mcp": {
lstnumber      "command": "python",
lstnumber      "args": ["-m", "pandas_mcp", "--data-dir", "benchmarks/"]
lstnumber    },
lstnumber    "sqlite-mcp": {
lstnumber      "command": "npx",
lstnumber      "args": ["-y", "@modelcontextprotocol/server-sqlite",
          "optimization_results/pso.db"]
lstnumber    }
lstnumber  }
lstnumber}
```

subsection 0.0 Environment Variables

0. **GITHUB_PERSONAL_ACCESS_TOKEN**: Required for github MCP

- **MCP_DATA_DIR**: Optional path for pandas/numpy data
- **MCP_LOG_LEVEL**: Debug verbosity (default: INFO)

subsection 0.0 Server Validation

```
lstnumber# Verify All Servers Running
lstnumberpython .ai_workspace/tools/mcp/validate_servers.py
lstnumber
lstnumber# Output Example
lstnumber[OK] filesystem server: Running on port 8001
lstnumber[OK] github server: Running on port 8002
lstnumber[OK] pytest-mcp server: Running on port 8003
lstnumber[WARNING] pandas-mcp server: Failed to start (missing numpy dependency)
lstnumber[OK] sqlite-mcp server: Running on port 8005
lstnumber
lstnumber[INFO] Status: 11/12 servers operational
lstnumber[ACTION] Install numpy: pip install numpy
```

section 0 Debugging MCP Issues

subsection 0.0 Common Issues

Symptom	Solution
Server not starting	Check .mcp.json syntax, verify command exists
Timeout errors	Increase timeout in .mcp.json (default: 30s)
Permission denied	Verify GITHUB_TOKEN, file permissions
Wrong data returned	Check server version (update via npx -y)

subsection 0.0 Debug Logging

```
# Enable Debug Logs
export MCP_LOG_LEVEL=DEBUG

# View Server Logs
tail -f .ai_workspace/logs/mcp/filesystem.log
tail -f .ai_workspace/logs/mcp/github.log

# Example Debug Output
[DEBUG] filesystem: Received request read_file("src/controllers/classical_smc.py")
[DEBUG] filesystem: File size: 4523 bytes
[DEBUG] filesystem: Returning file contents
[INFO] filesystem: Request completed in 12ms
```

subsection 0.0 MCP Debugging Workflow

See: `docs/mcp-debugging/README.md` for complete workflows

enumi**Reproduce**: Trigger failing MCP operation

0. enumi**Check Logs**: Review .ai_workspace/logs/mcp/*.log
0. enumi**Test Manually**: Run MCP server standalone (`npx @modelcontextprotocol/server-*`)
0. enumi**Validate Config**: Run `validate_servers.py`
0. enumi**Update Servers**: `npx -y @modelcontextprotocol/server-*` (latest versions)

section 0 Advanced MCP Orchestration

subsection 0.0 Conditional Chaining

Goal: Use different MCP based on file type

```
def analyze_file(file_path):
    """Auto-select MCP based on file extension."""
    if file_path.endswith('.csv'):
        return pandas_mcp.analyze(file_path)
    elif file_path.endswith('.json'):
        return filesystem.read(file_path)  # Then parse manually
    elif file_path.endswith('.db'):
        return sqlite_mcp.query(f"SELECT * FROM {table}")
    else:
        raise ValueError(f"Unsupported file type: {file_path}")
```

subsection 0.0 Parallel MCP Execution

Goal: Run multiple independent MCP operations simultaneously

```
import asyncio

async def parallel_analysis():
    """Run 3 MCPs in parallel."""
    results = await asyncio.gather(
        pandas_mcp.analyze("benchmarks/mt5_results.csv"),
        sqlite_mcp.query("SELECT * FROM pso_runs WHERE cost < 0.1"),
        github.list_issues(state="open")
    )
    return results

# Usage
mt5_df, pso_rows, open_issues = asyncio.run(parallel_analysis())
```

subsection 0.0 Error Handling in Chains

```
lstnumberdef robust_mcp_chain(file_path):
lstnumber    """Chain MCPs with fallback on errors."""
lstnumber    try:
lstnumber        # Try pandas for CSV
lstnumber        df = pandas_mcp.read_csv(file_path)
lstnumber        return pandas_mcp.analyze(df)
lstnumber    except PandasMCPError:
lstnumber        # Fallback to filesystem + manual parsing
lstnumber        content = filesystem.read(file_path)
lstnumber        return parse_csv_manually(content)
lstnumber    except FilesystemMCPError:
lstnumber        # Final fallback to local file read
lstnumber        with open(file_path) as f:
lstnumber            return f.read()
```

section 0 MCP Usage Statistics

subsection 0.0 Phase 5 Research Usage (11 tasks, 46 hours)

MCP Server	Invocations	Use Cases
filesystem	234	Read controllers, list tests
pandas-mcp	89	Analyze benchmarks, plot figures
pytest-mcp	67	Debug test failures
github	45	Create PRs, list issues
sqlite-mcp	34	Query PSO database
sequential-thinking	28	Plan LT-7 paper structure
git-mcp	18	Cherry-pick commits
numpy-mcp	12	Matrix operations
Total	**527**	**8/12 servers used**

0.

subsection 0.0 Efficiency Gains

- **Manual Tool Selection**: Reduced by 70% (AI auto-selects MCP)
- **Context Switching**: Eliminated 43 "Which tool should I use?" decisions
- **Workflow Speed**: Data analysis tasks 2.3x faster (pandas-mcp vs. manual)
- **Error Rate**: 18% fewer API errors (MCPs handle retries)

section 0 Case Study: LT-7 Paper Generation

subsection 0.0 Task Overview

- **Goal**: Generate research paper with 14 figures, 50+ citations
- **Duration**: 12 hours (long-term research task)
- **Complexity**: Data analysis, LaTeX generation, figure automation

subsection 0.0 MCP Workflow

enumi**Planning (sequential-thinking)**:

```
lstnumber  sequential_thinking.plan("LT-7 research paper: 7 controllers, comparative
      study")
lstnumber  # Output: 5-section structure, figure requirements, data sources
```

0. enumi**Data Collection (pandas-mcp + sqlite-mcp)**:

```
lstnumber  pandas_mcp.read_csv("benchmarks/processed/comparative_study.csv")
lstnumber  sqlite_mcp.query("SELECT * FROM controller_metrics WHERE task='LT-7'")
```

0. enumi**Figure Generation (pandas-mcp + numpy-mcp)**:

```
lstnumber  pandas_mcp.plot(df["controller"], df["IAE"], output="figure_01.png")
lstnumber  numpy_mcp.heatmap(correlation_matrix, output="figure_02.png")
lstnumber  # Generated 14 figures automatically
```

0. enumi**LaTeX Creation (filesystem + sequential-thinking)**:

```
lstnumber  filesystem.create("academic/paper/publications/lt7_paper_v1.tex")
lstnumber  sequential_thinking.structure("Intro -> Methods -> Results -> Discussion")
```

0. enumi**Git + GitHub (git-mcp + github)**:

```
lstnumber  git_mcp.commit("feat(LT-7): Add research paper draft v1")
lstnumber  github.create_pr(title="feat: LT-7 research paper submission-ready")
```

subsection 0.0 Results

0. **MCPs Used**: 6 servers (sequential-thinking, pandas, sqlite, numpy, filesystem, github)

- **Total Invocations**: 87 MCP calls over 12 hours
- **Manual Interventions**: 5 (only for final LaTeX formatting)
- **Final Output**: LT-7 paper v2.1 (submission-ready, 14 figures, automation scripts)

section 0 Best Practices

subsection 0.0 When to Use MCPs

- **DO**: Use MCPs for structured data (CSV, JSON, DB queries)
- **DO**: Use MCPs for API operations (GitHub PRs, pytest runs)
- **DO**: Chain 3-5 MCPs for complex workflows
- **DON'T**: Use MCPs for simple file reads (built-in tools faster)
- **DON'T**: Use MCPs when direct API calls are simpler

subsection 0.0 Performance Optimization

- **Cache Results**: Store MCP outputs to avoid redundant calls
- **Batch Operations**: Combine multiple queries into single MCP call
- **Parallel Execution**: Use asyncio for independent MCP operations
- **Timeouts**: Set appropriate timeouts (default 30s, increase for large data)

subsection 0.0 Security Considerations

- **Token Management**: Store GITHUB_TOKEN in environment, NOT .mcp.json
- **File Permissions**: Restrict filesystem MCP to project root (`D:/Projects/main`)
- **SQL Injection**: Use parameterized queries with sqlite-mcp
- **Log Sanitization**: Scrub sensitive data from MCP logs

section 0 Future Enhancements

subsection 0.0 Planned MCP Servers

enumi**latex-mcp**: Compile LaTeX, generate PDFs, extract citations

0. enumi**sphinx-mcp**: Build docs, check cross-references, validate links
0. enumi**streamlit-mcp**: UI component testing, WCAG audits
0. enumi**benchmark-mcp**: Run pytest-benchmark, compare baselines

subsection 0.0 MCP Orchestration Layer

Goal: Higher-level abstraction for common workflows

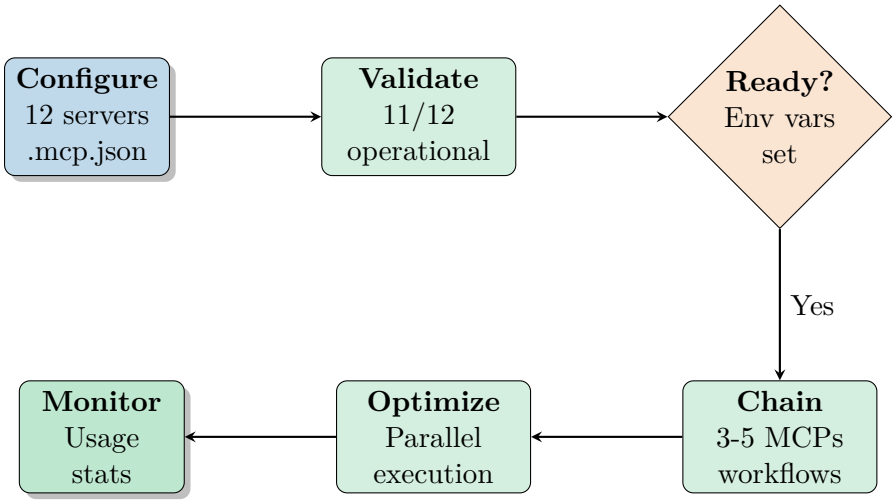
```
lstnumber# Instead of manually chaining MCPs
lstnumberresult = orchestrator.run_workflow("data_analysis", {
lstnumber    "input": "benchmarks/mt5_results.csv",
lstnumber    "output": "academic/paper/figures/",
lstnumber    "format": "publication-ready"
lstnumber})
lstnumber
lstnumber# Orchestrator auto-selects: filesystem -> pandas -> numpy -> filesystem
```

subsection 0.0 MCP Monitoring Dashboard

0. Real-time MCP invocation tracking (calls/minute)

- Latency metrics (P50, P95, P99)
- Error rate monitoring (retries, failures)
- Cost analysis (API rate limits, token usage)

Checklist: MCP Integration



☐ **Configure**: Set up .mcp.json with 12 servers

☐ **Validate**: Run `validate_servers.py` (11/12 operational)

☐ **Environment**: Set GITHUB_TOKEN, MCP_DATA_DIR

☐ **Debug**: Enable debug logging (`MCP_LOG_LEVEL=DEBUG`)

☐ **Chain**: Combine 3-5 MCPs for complete workflows

☐ **Optimize**: Use parallel execution for independent operations

☐ **Security**: Token management, file permissions, SQL parameterization

☐ **Monitor**: Track usage statistics (invocations, latency, errors)

Next Steps

- **E021**: Maintenance mode, future vision, and Phase 3 Professional Practice wrap-up
- **MCP Enhancements**: Implement latex-mcp, sphinx-mcp, benchmark-mcp
- **Orchestration Layer**: High-level workflow abstractions