Identifier Splitting for SBSE Software Maintenance

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SBSE: Search-based Software Engineering

- **Formulating common software engineering problems in terms of a search-based optimisation problem**
  - Many competing and complex objectives
  - Large search spaces

- **Search based software engineering research has gained much interest in recent years** [10]
  - Improvements to software engineering processes
  - Quality of code produced

Software Maintenance

- **60/60 rule exists in software development**
  - Maintenance costs dominate development costs at around 60% [8]
  - Further, 60% of maintenance costs consumed by enhancement alone [8]

- **Steps therefore must be taken to reduce maintenance costs over the lifetime of a project**

Identifiers

- **Identifier names in source code are natural language tokens used to label program entities**
  - Including; variables/constants, methods/functions, classes and objects in OOP etc.

- **Notationally, they can be described as a character sequence** '$C\{c_0, \ldots, c_n\}$' [11]
  - *Where a character c_i can be a letter, digit or special character*

Identifiers

- **The natural language of identifier names captures**:
  - Domain-specific knowledge
  - Clues to programming intention

- **Much research exists exploring the role identifiers and the language used for the human comprehension of source code**
  - E.g. concise and consistent naming [4]

Identifiers: Composition

- **Programming languages and programming conventions place constraints on form and content of identifier names** [1]
  - Programming languages impose hard constraints
    - *You can be sure constraints are followed*
  - Programming conventions impose soft constraints
    - *Not applied universally*

- **Fully Autonomous techniques should be able to handle both conventionally and unconventionally constructed identifiers** [1]

Identifier Splitting Problem

- **Defined as the identification of the component words in identifiers, where:**
  - No explicit boundary
  - Present, but open to misinterpretation
- **Involves the solution to two sub-problems**
  - Mixed-case tokenisation [5,11]
  - Same-case tokenisation [5,11]
- **Often extended to include abbreviation expansion**
  - **E.g. HTTP = {hyper, text, transfer, protocol}**

Mixed-case

- **Involves the tokenisation of identifiers containing internal capitalisation boundaries** [1,5]
  - Lower to upper case (LCUC) e.g. getIdentifier
  - Upper to lower case (UCLC) e.g. XMLParser
- **LCUC transitions readily tokenised** [1, 5]
  - Well defined boundary between words i.e. easily identified
  - Conventional
- **UCLC has two possible boundaries** [1, 5]
  - GPSstate → {GP, Sstate} according to camel-casing
  - GPSstate → {GPS, state} according to alternative split

Mixed-case: UCLC

- **Has been addressed (somewhat) using dictionary-based scoring metrics**
  - Samurai Identifier Splitter [enslen]
  - Identifier Name Tokeniser Tool (INTT) [1]

- **But what about…**
  - Unconventional acronyms e.g. ‘connectDnDServer’
  - Acronyms/words with bounding digits e.g. ‘*POP3Server*’
    - *Pop3Server* doesn’t solve this problem
    - What about ‘*Cad3DModel*’?
  - Ambiguous boundaries e.g. ‘*GPRSend*’

Same-case

- **Sub-problem addresses the tokenisation of same-case multi word identifiers** [1, 5]
  - E.g. MAXVALUE or thenewestone

- **Existing techniques mainly rely on words being found in a dictionary**
  - Sometimes more than one dictionary e.g. abbreviations
  - But no dictionary can ever be complete
    - Invented words for some new concept
    - Neologisms e.g. ‘devoidify’, ‘detokenated’, ‘pathinate’, ‘precisify’ [1]

Motivation

- **Tools used to aid program comprehension**
  - Particularly during maintenance tasks
- **Many existing analysis tools don't leverage natural language**
  - Arguably, domain knowledge and programming intention is more informative to a programmer
- **Tools have emerged that exploit this natural language information** [12]
  - Natural Language Program Analysis (NLPA)

Motivation

- **To process natural language, accurate tokenisation is a necessary first step**
  - Words have individual meanings and probably have a different or no meaning while un-tokenised

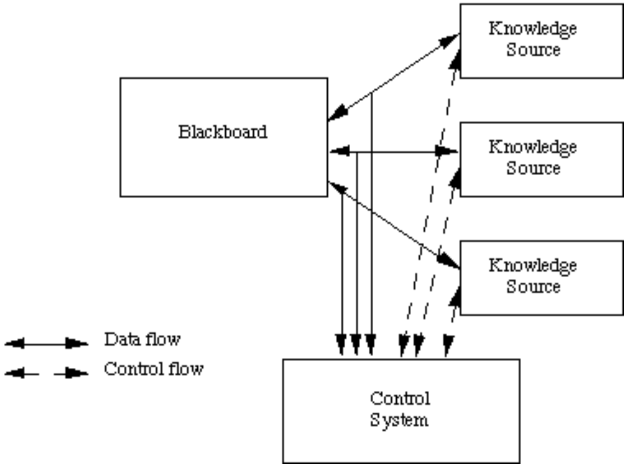
- **Incorrect tokenisation at this stage can propagate errors to later processes during program analysis** [1]

Tokenisation for Humans

- **For us the notion of splitting identifiers seems easy:**
  - E.g. tokenise: '*yankeedoodlewenttolondonridingonapony*'
- **We have the advantage of higher-level strategies on our side**
  - We have many a mental dictionary, an idea of probable word frequencies, n-gram frequencies, letters never seen together, context checking etc. etc.
  - We can apply all of these or only some of these to give evidence for a split point
  - We can even invent/analogise new methods from old ones
  - We can adapt to new information and change our conclusions and approach accordingly
- **For identifier splitting, we need our approaches to do the same**

Proposed Solution: Blackboard Architecture

- **A multi-agent problem solving architecture**
  - Opportunistic Problem Solving Model
- **First developed as a means to recognise vocal speech**
  - Hearsay II [6]
- **Involves 3 main components:**
  - Agents/Knowledge Sources
  - Blackboard/Global Workspace
  - Control Mechanism



Blackboard Architecture: Metaphor

The first week of the brainstorming session went slowly.

Courtesy of www.gograph.com

Blackboard Architecture: Characteristics

- Modularity
- Diversity of Problem Solving Techniques
- Flexible Representation of Information
- Common Interaction Language
- Event-driven Triggers
- Need for a Control Mechanism

Blackboard Architecture: Benefits to Tokenisation

- **Components can be applied at the most opportune time**
  - Some operations best performed before others
    - E.g. for ‘connectDnDServer’
- **Heterogeneous components and representations can easily collaborate in a blackboard system**
  - E.g. Neural net splitter [7] and graph-based tokenisation & abbreviation expansion [9, 3]
- **Supports concurrency of problem solving processes**
  - On multiple levels of speciality and granularity

End of the Line

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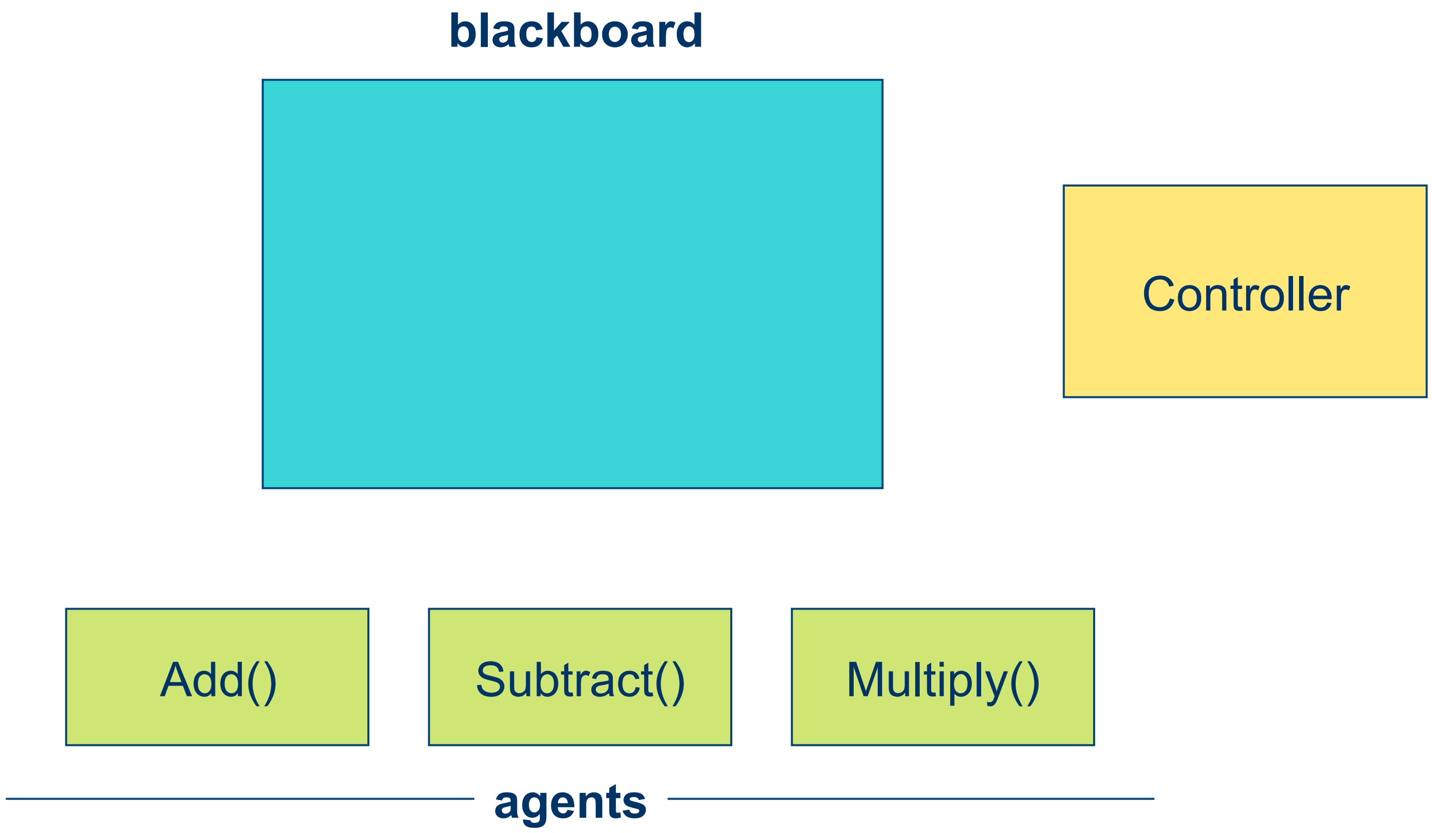
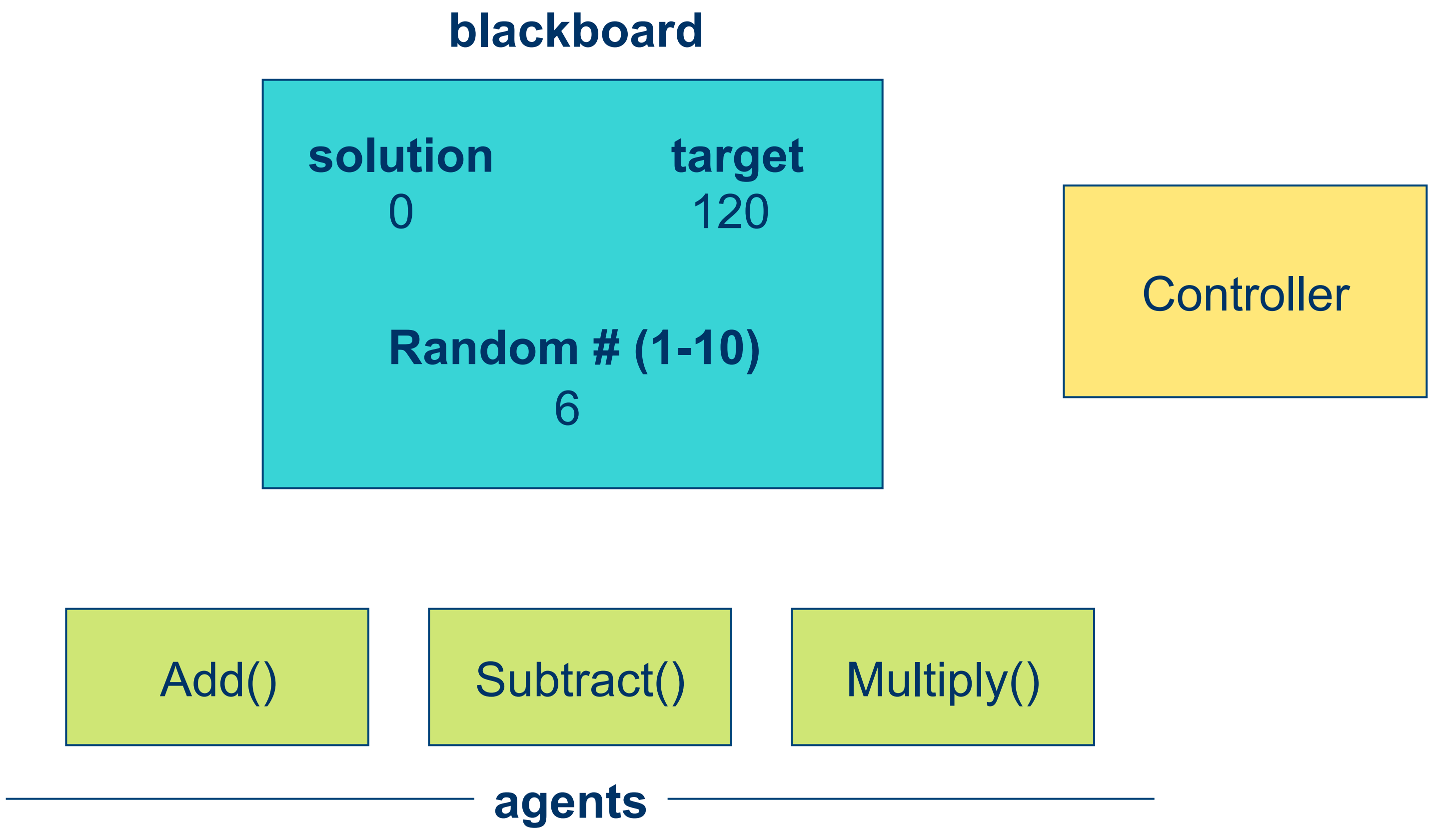
Example



Example: Iteration 1



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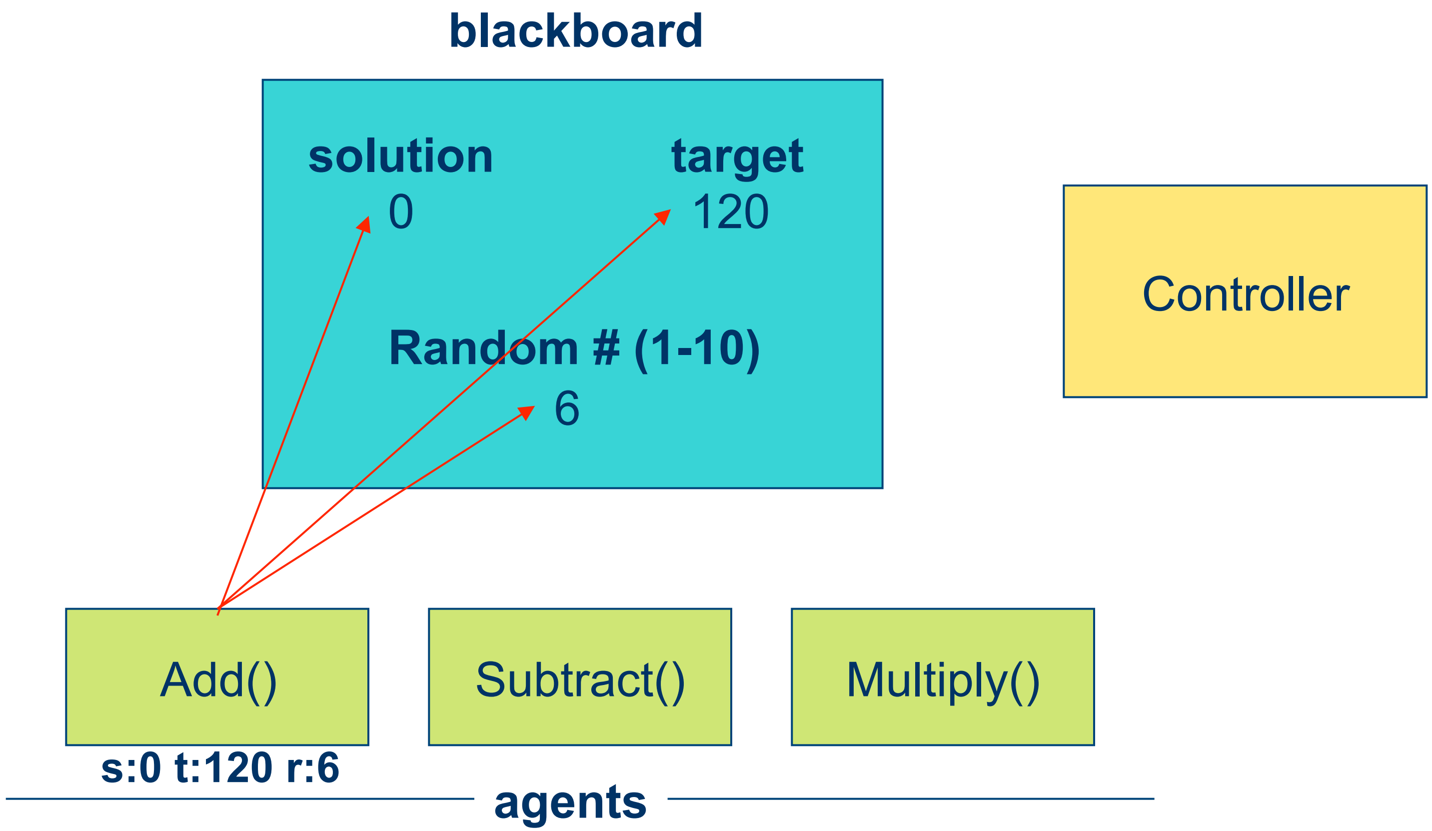

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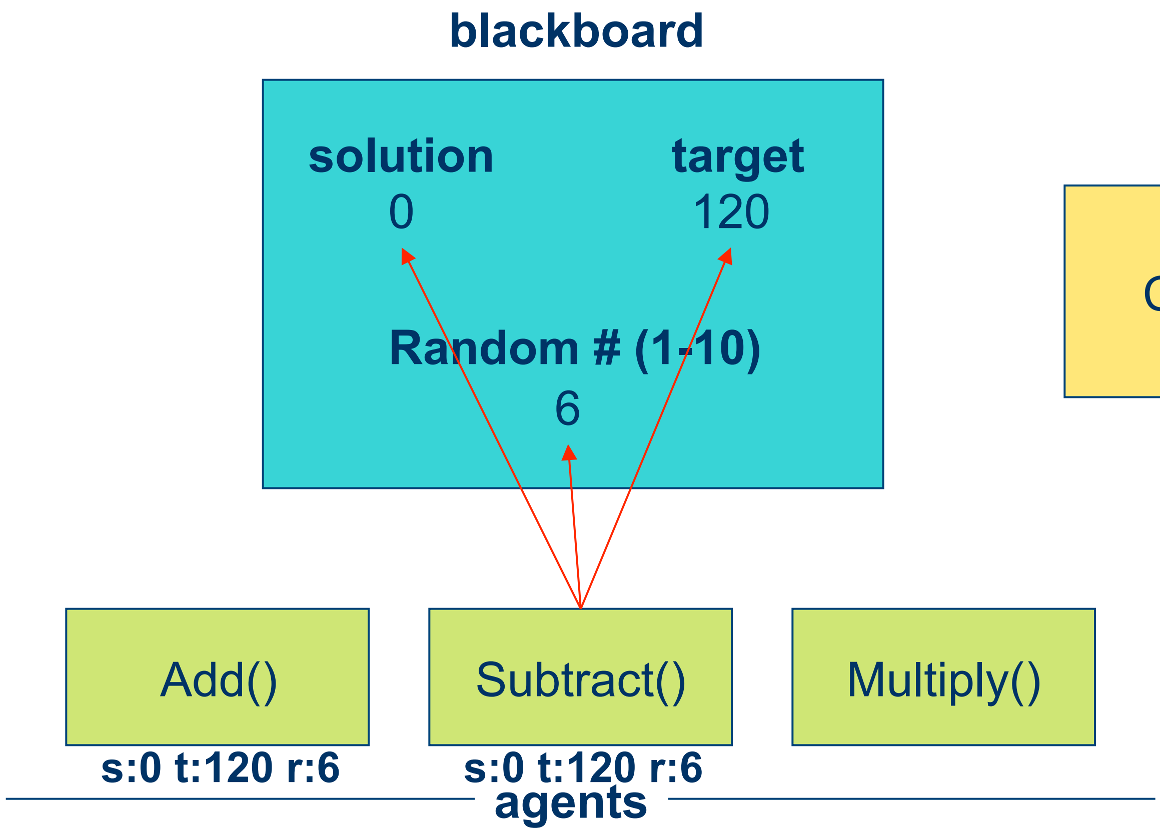

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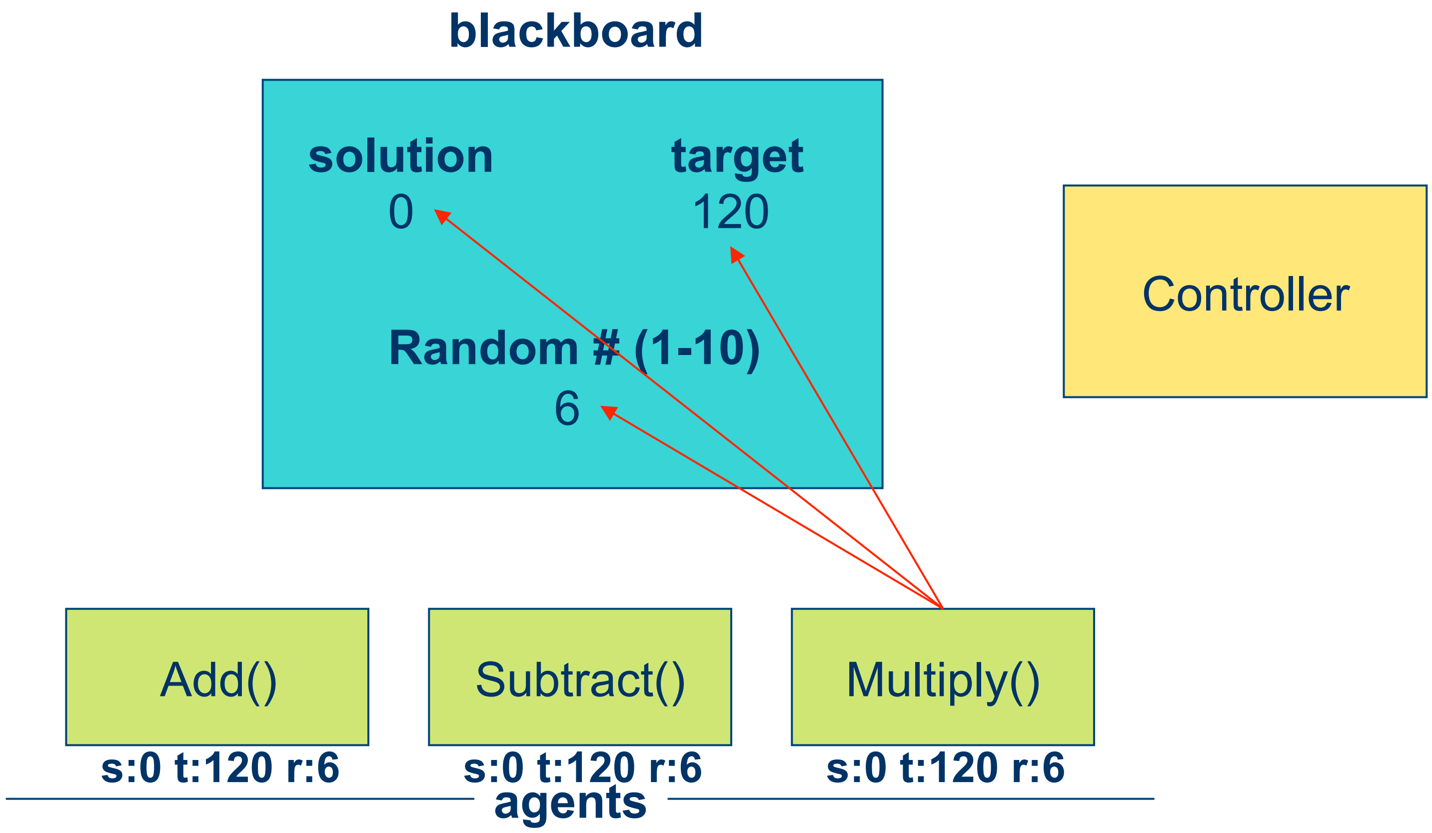

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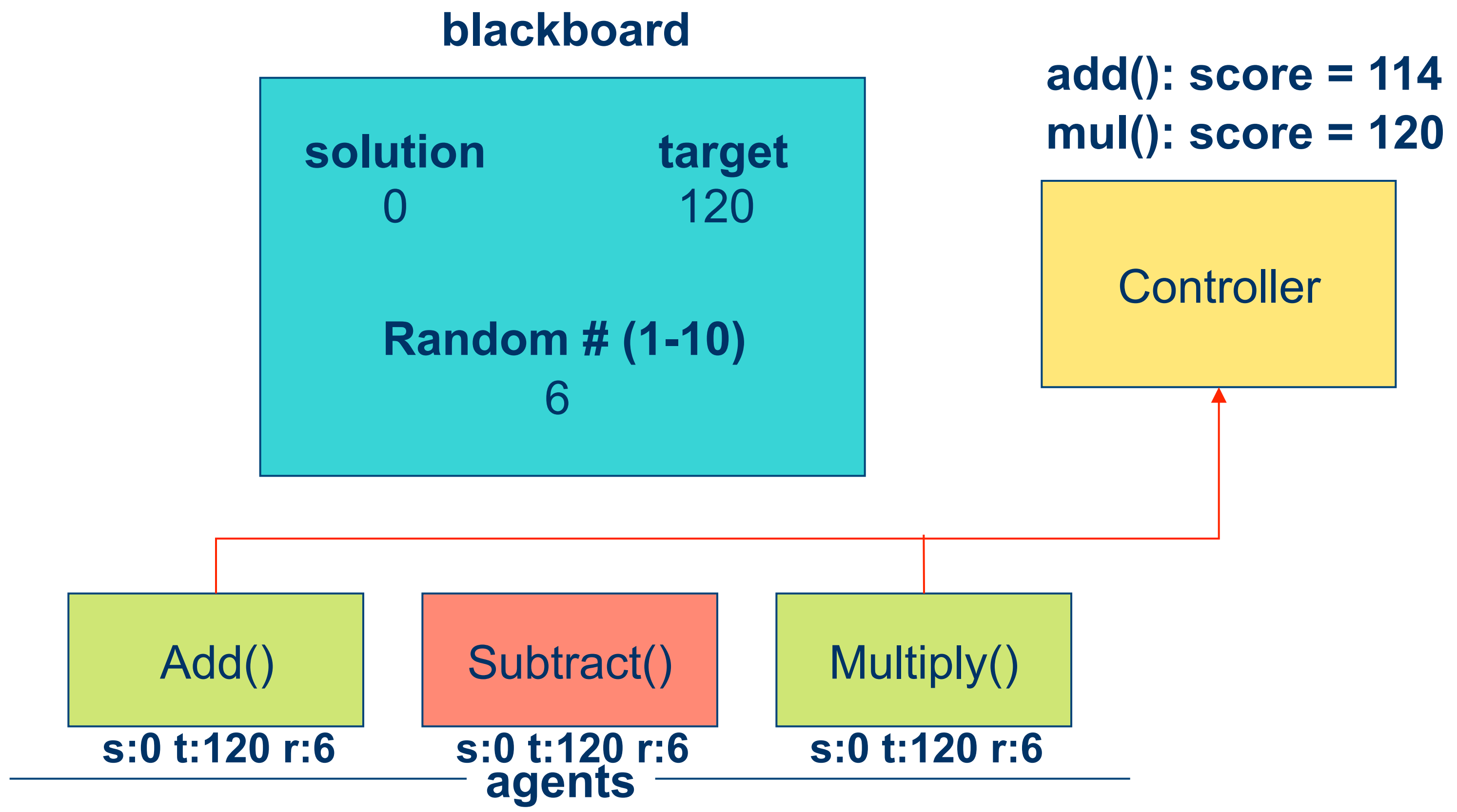

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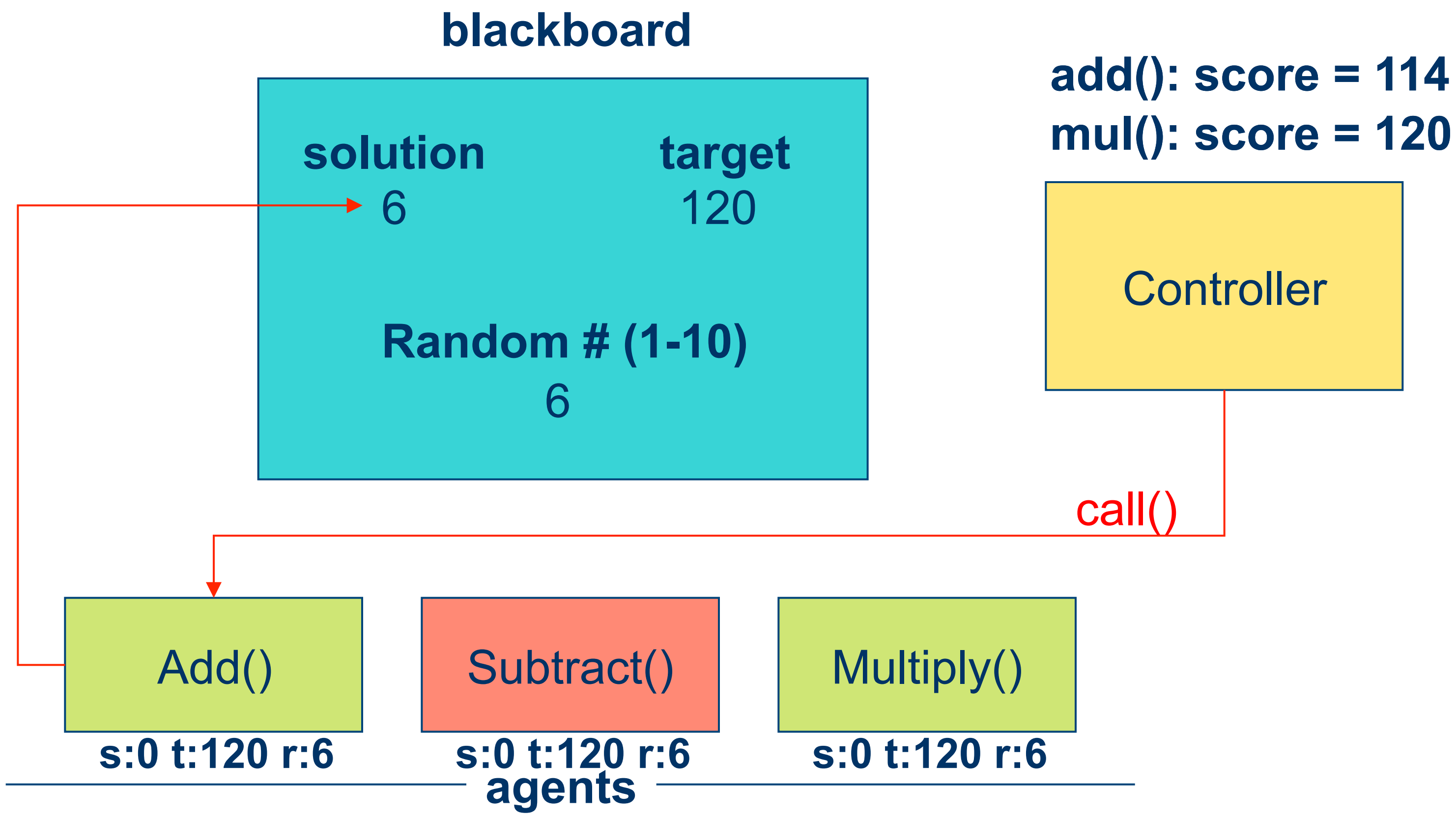

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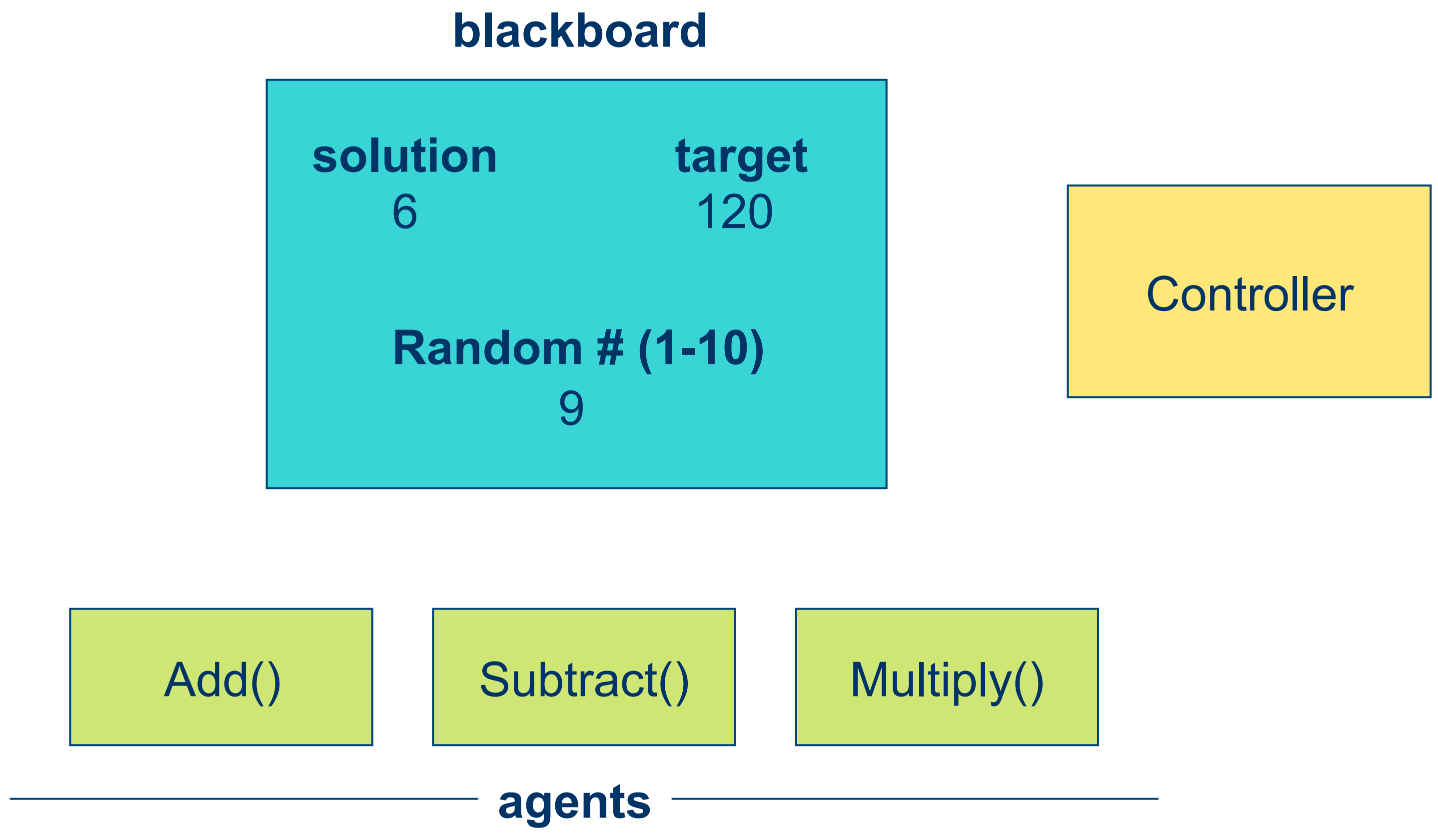

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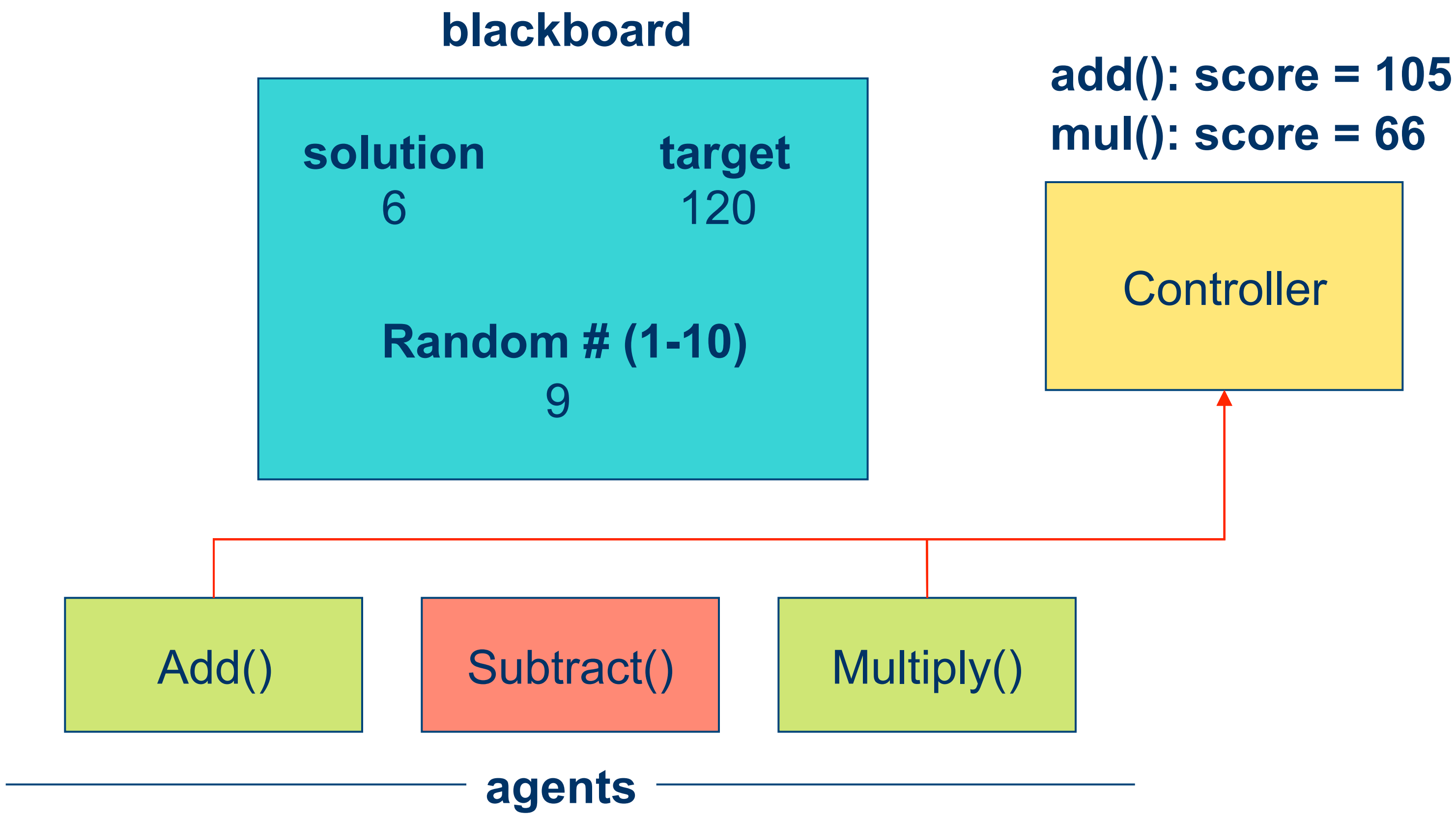

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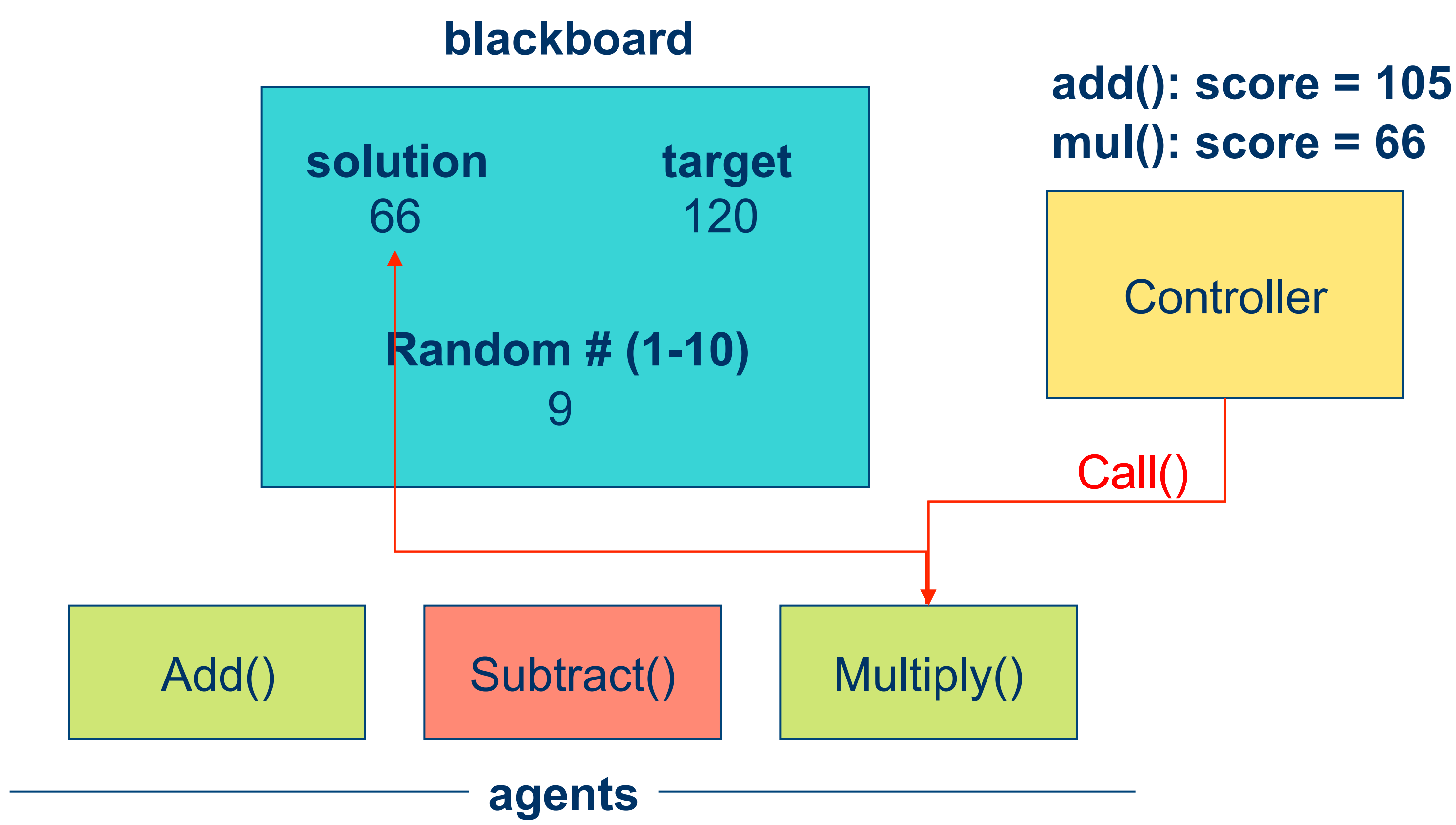

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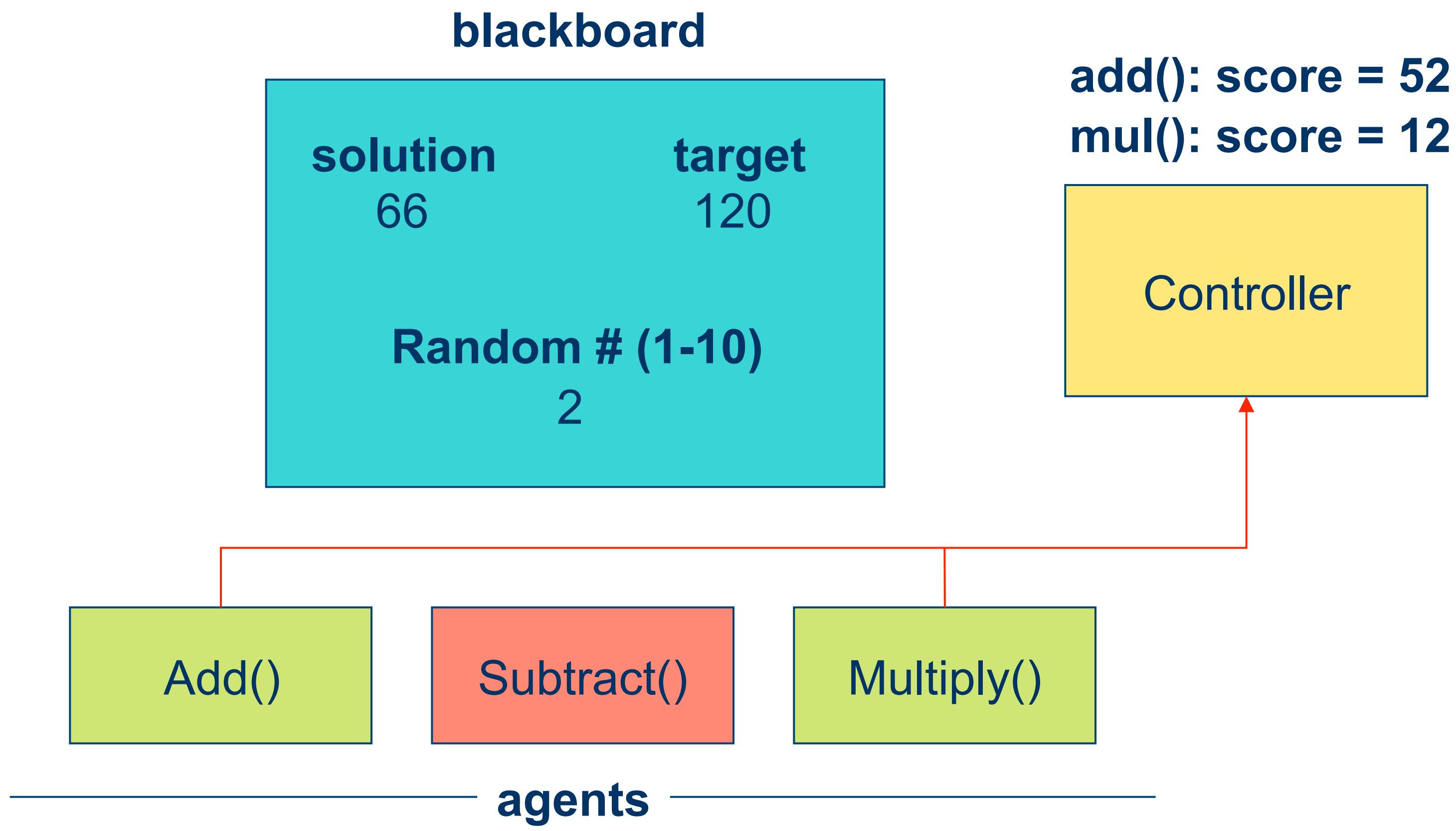
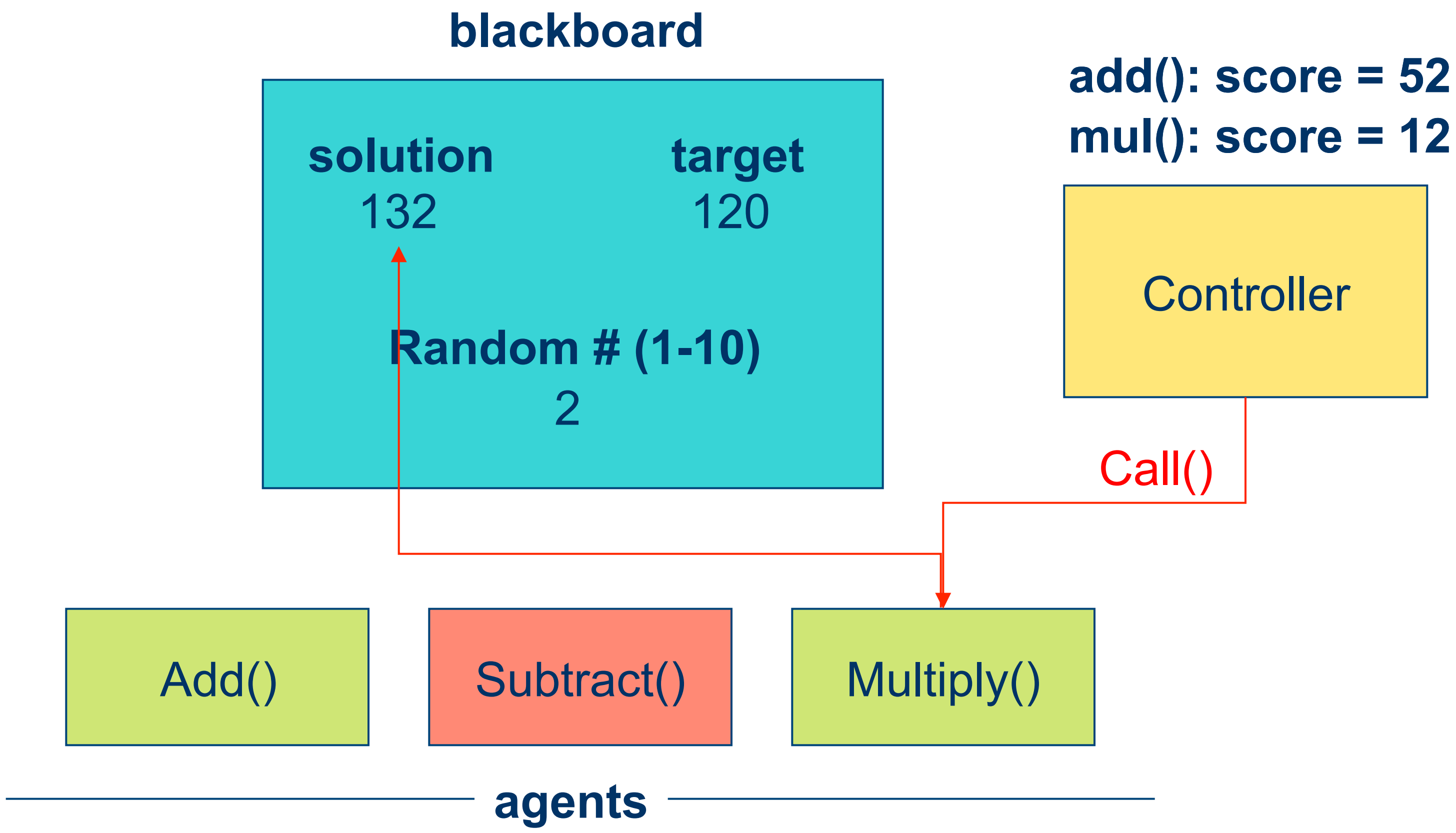


Example: Iteration 3



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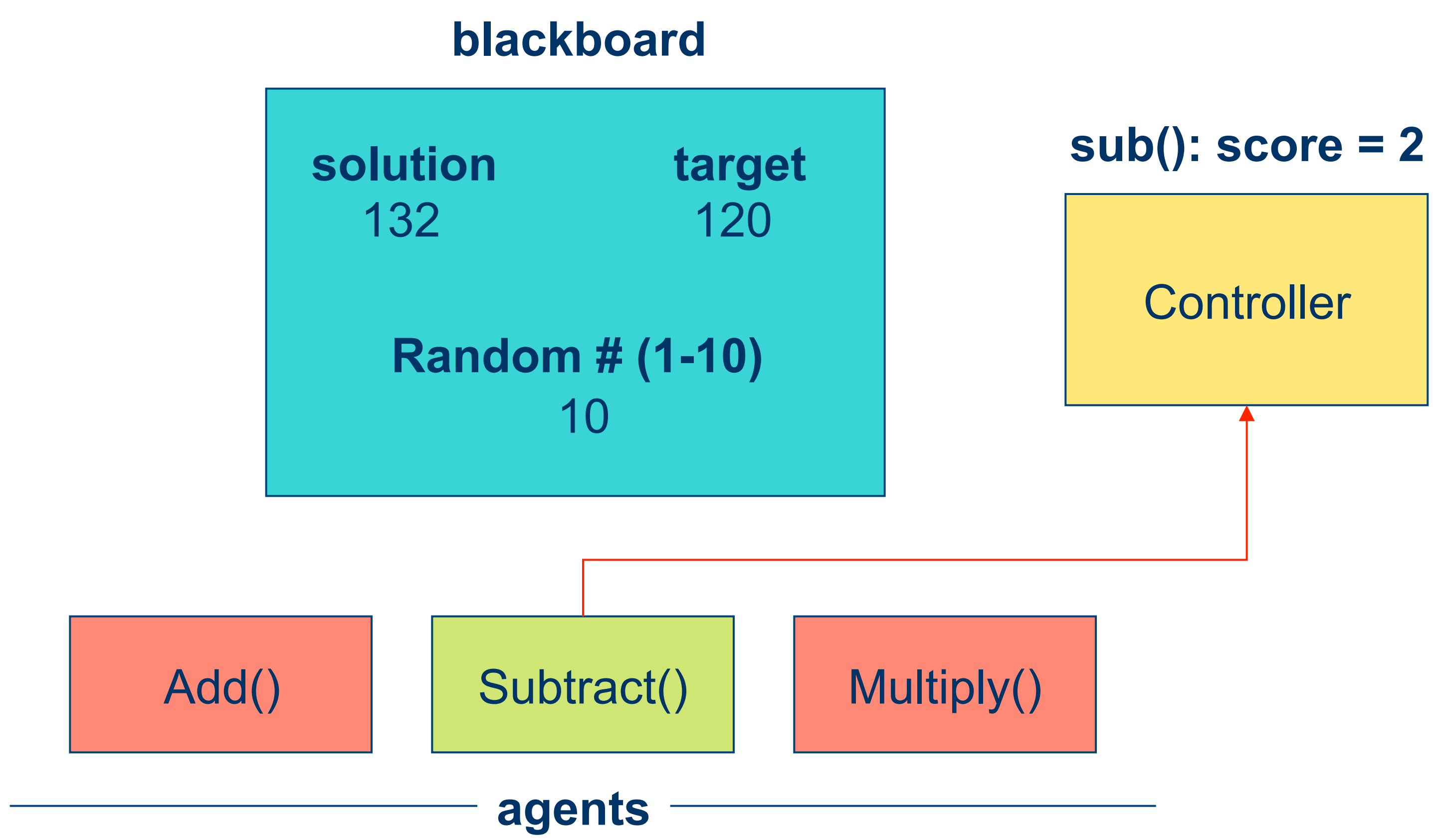

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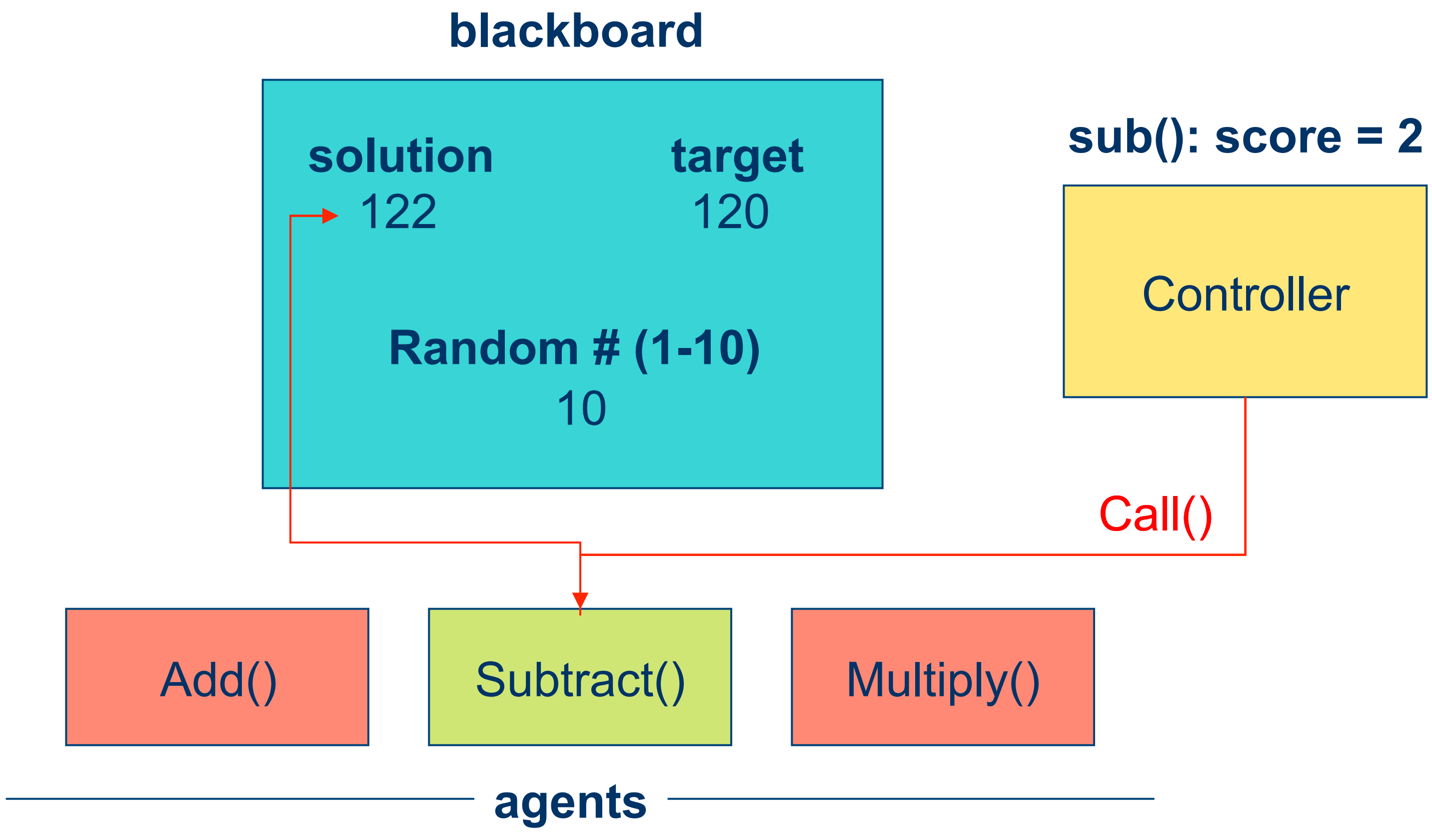

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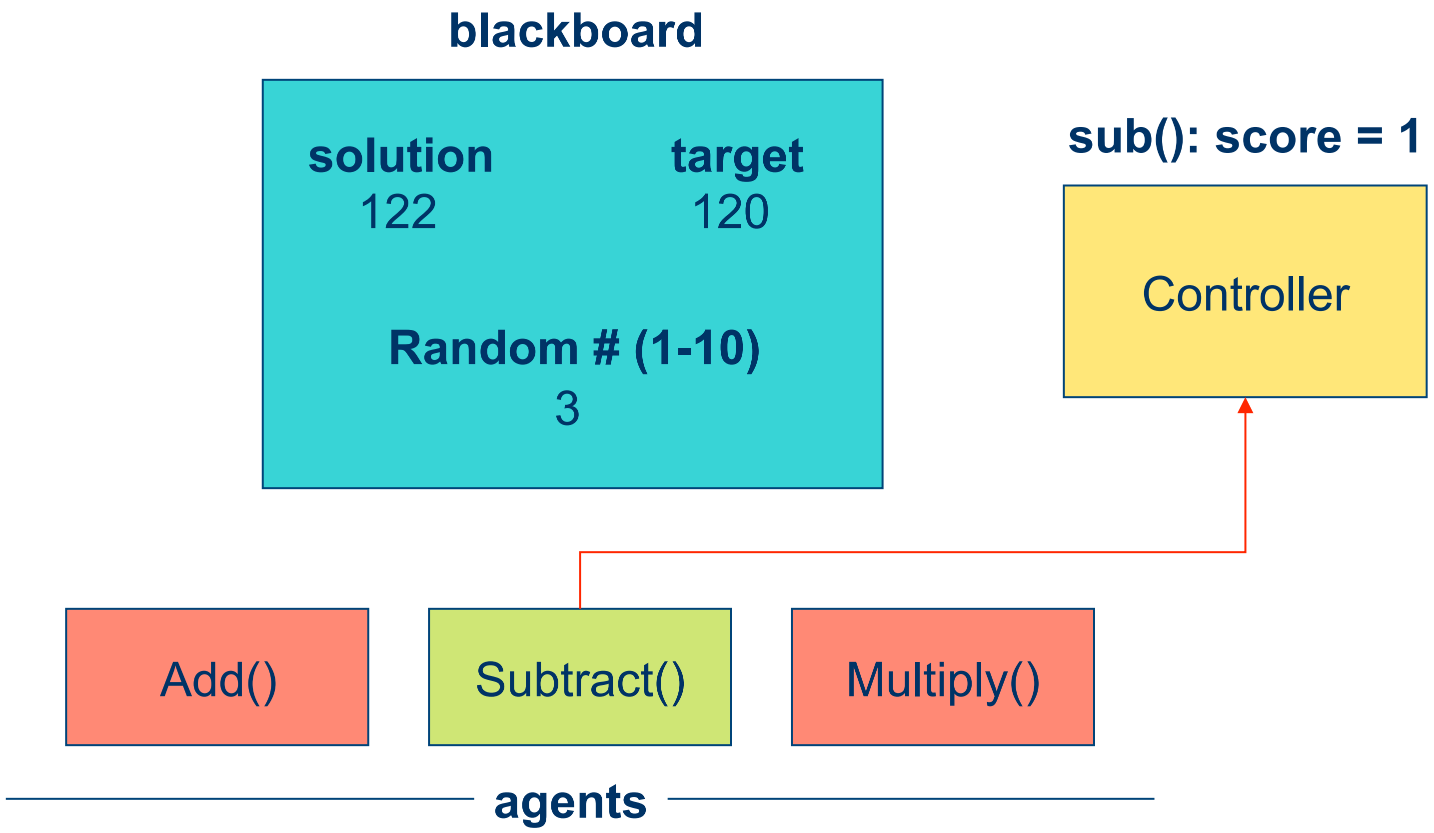

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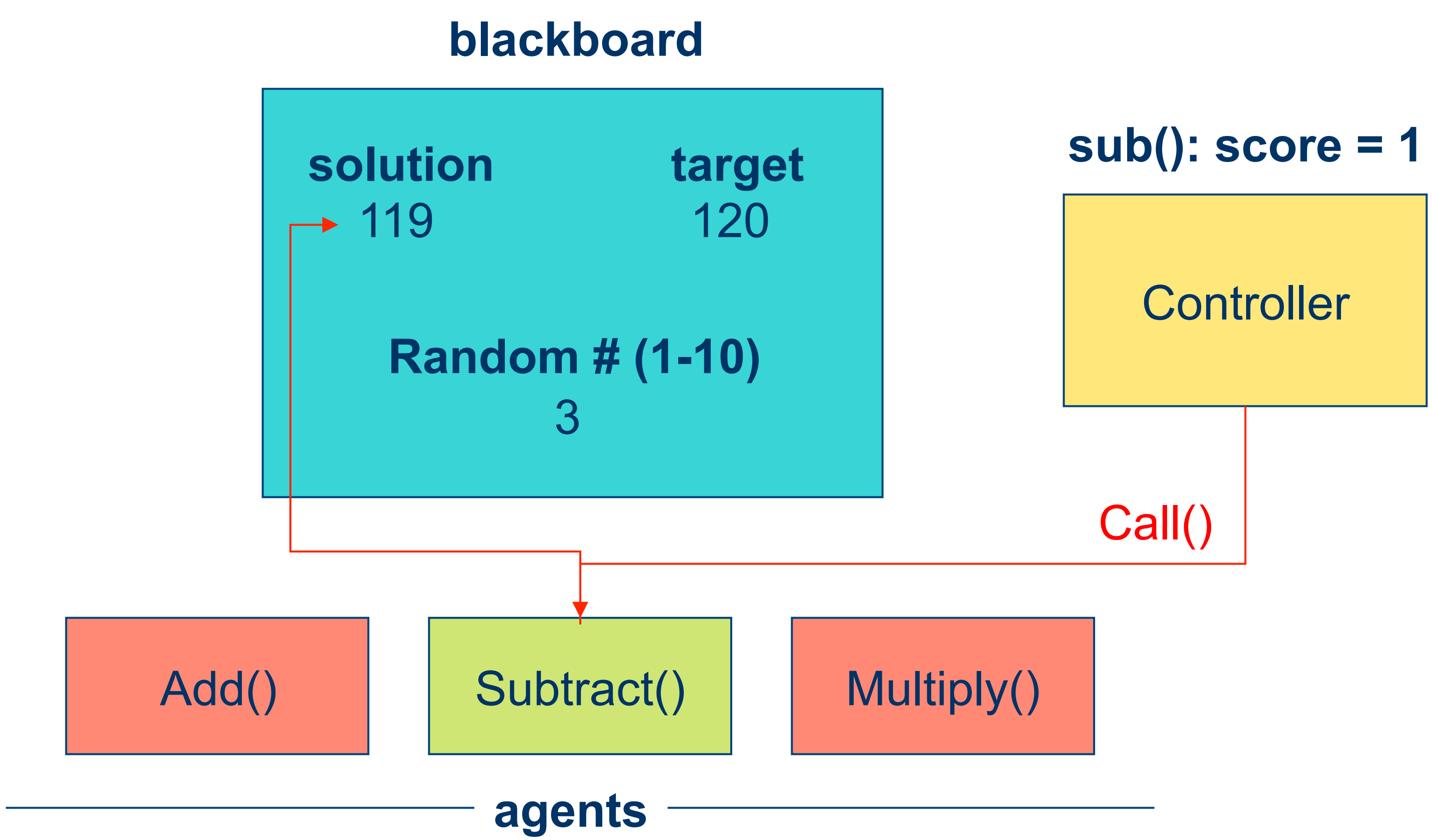

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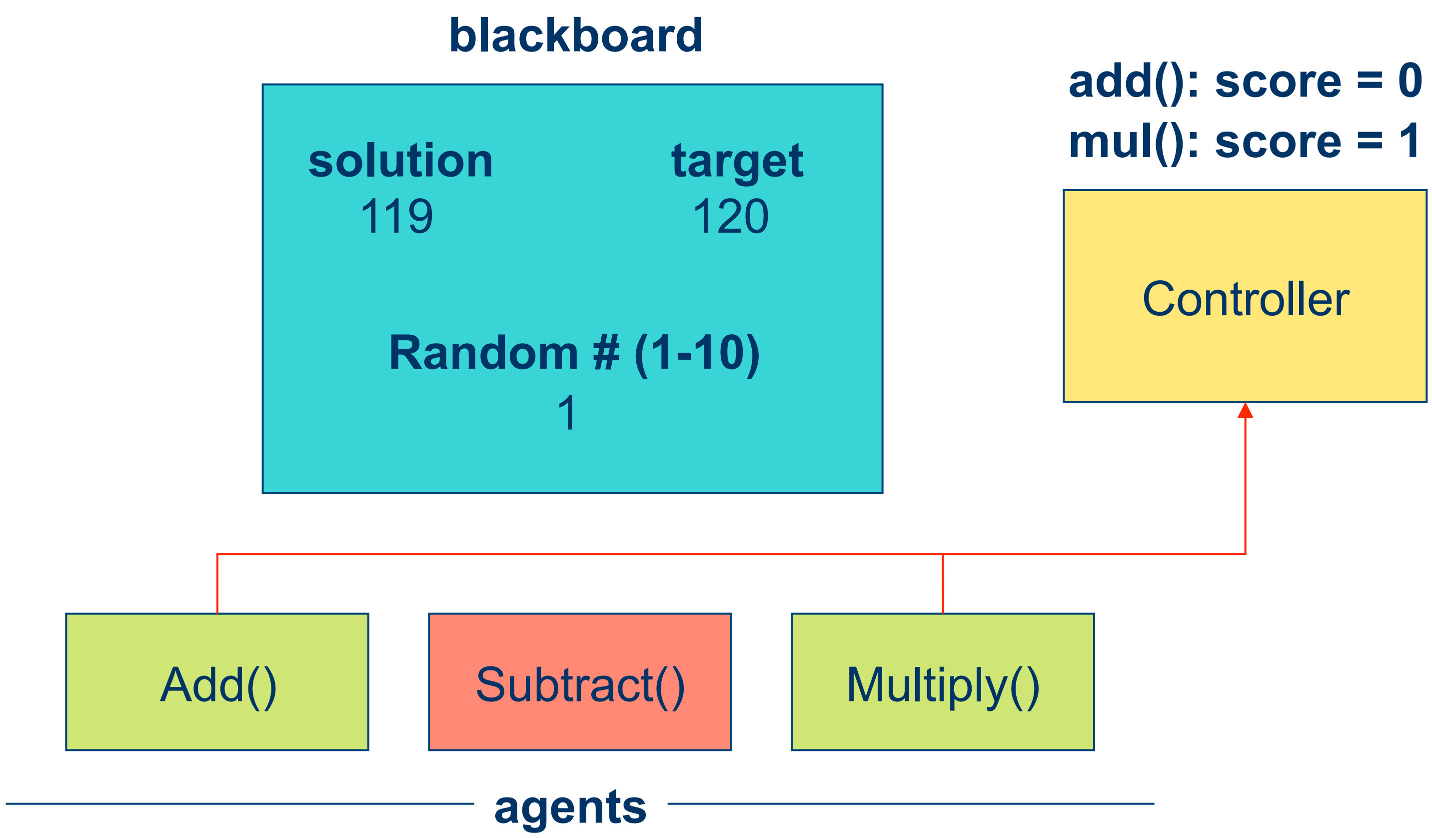

Example: Iteration 6