SWE 621:
Software Modeling and Architectural Design

Lecture Notes on Software Design

Lecture 9 – Task Structuring

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Lecture 9: Task Structuring

Hassan Gomaa

Reference: H. Gomaa, Chapters 18 - *Software Modeling and Design*, Cambridge University Press, February 2011

Reference: H. Gomaa, Chapter 14 - *Designing Concurrent, Distributed, and Real-Time Applications with UML*, Addison Wesley Object Technology Series, July, 2000

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Steps in Using COMET/UML

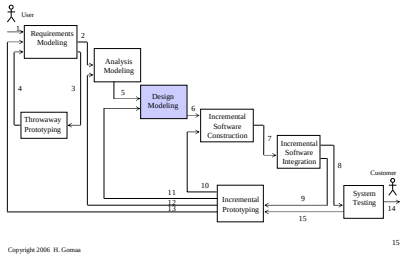
1 Develop Software Requirements Model

2 Develop Software Analysis Model

3 **Develop Software Design Model**

- Design Overall Software Architecture (Chapter 12, 13)
- Design Distributed Component-based Subsystems (Chapter 12-13,15)
- **Structure Subsystems into Concurrent Tasks (Chapter 18)**
- Design Information Hiding Classes (Chapter 14)
- Develop Detailed Software Design

Figure 6.1 COMET object-oriented software life cycle model

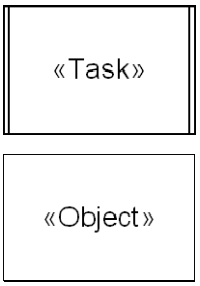


Structure System into Tasks

- Concurrent Design with UML
- Concurrent task structuring criteria
  - Structure analysis model into concurrent tasks
    - Task is an active object
    - Task has thread of control
  - Consider concurrent nature of system activities
  - Determine concurrent tasks
- Define task interfaces
- Support for concurrent tasks
  - Operating system services: multi-tasking kernel

Active and Passive Objects

- Objects may be **active** or **passive**
- **Active object**
  - **Concurrent Task**
  - Has thread of control
- **Passive object**
  - a.ka. **Information Hiding Object**
  - Has no thread of control
  - Operations of passive object are executed by task
  - Operations execute in task's thread of control
    - Directly or indirectly
- Software Design terminology
  - **Task** refers to active object
  - **Object** refers to passive object



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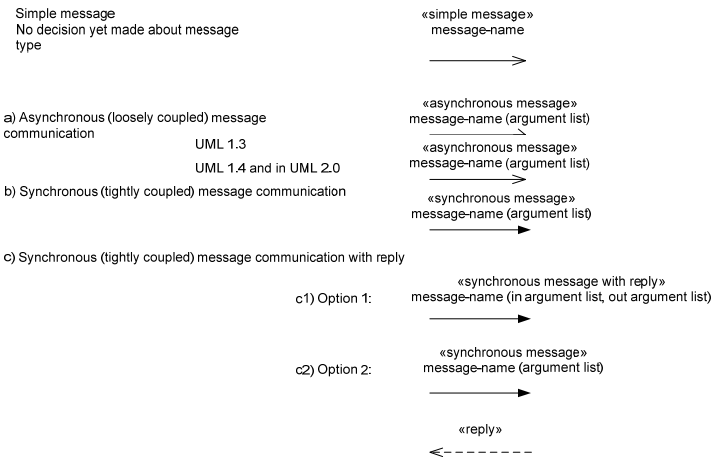
UML notation for messages



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Task Structuring Criteria

- Event driven task
  - Activated by external event (e.g., interrupt)
- Periodic task
  - Activated by timer
- Demand driven task
  - Activated by arrival of internal message

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I/O Task Structuring Criteria

- Event driven I/O task
  - Task for each event (interrupt) driven I/O device
  - Event driven device generates interrupt
- Periodic I/O task
  - Task for each polled I/O device
  - I/O device (usually input) sampled at regular intervals
- Demand driven I/O task
  - Task for each passive I/O device (usually output)
  - Computation overlapped with output

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Event Driven I/O Task

Device Driver

- One task for each event driven I/O device
- Activated by device I/O interrupt
- Reads input
- Converts to internal format
- Disposes of input
  - Sends message containing data
  - Signals event (message with no data)
  - Writes to data store

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Figure 18.5 Example of event driven I/O task

Figure 18.5a Analysis model – communication diagram

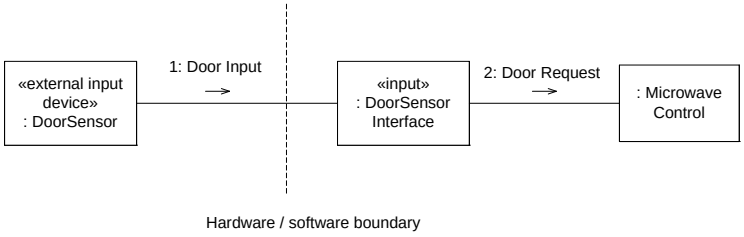
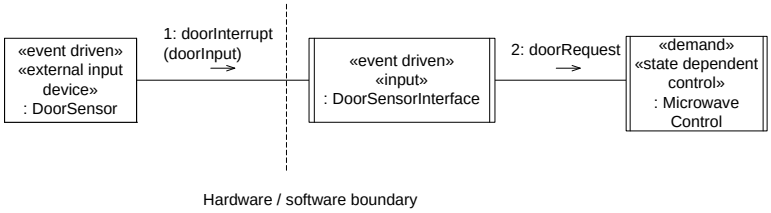


Figure 18.5b Design model – concurrent communication diagram



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Periodic I/O Task

Task for each polled I/O device
- Activation of task is periodic
- Samples I/O device

Periodic I/O task
- Activated by timer event
- Performs I/O operation
- Waits for next timer event

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Figure 18.6 Example of a periodic I/O task

Figure 18.6a Analysis model – communication diagram

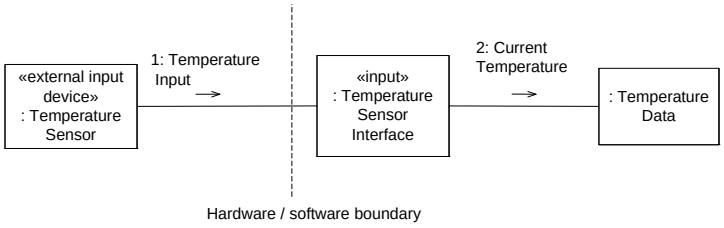
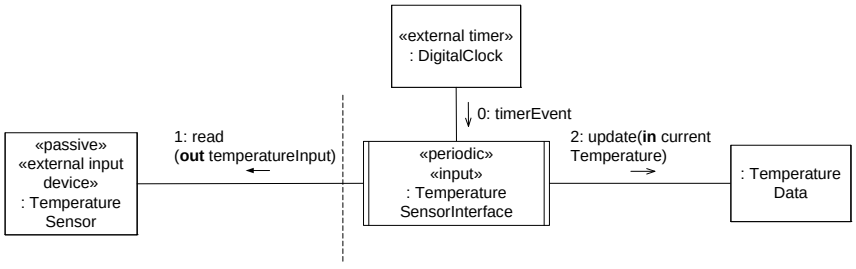


Figure 18.6b Design model – concurrent communication diagram



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Demand Driven I/O Task

- Task for each passive I/O device (usually output)
  - Passive I/O device does not need to be polled
  - Computation overlapped with output
    - Task output to device overlapped with
    - Computational task that produces data
- Usually for passive output device
  - Demand driven I/O task
- Passive input devices more likely to be polled
  - Periodic input task

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Figure 18.7 Example of a Demand Driven Output Task

Figure 18.7a Analysis model – communication diagram

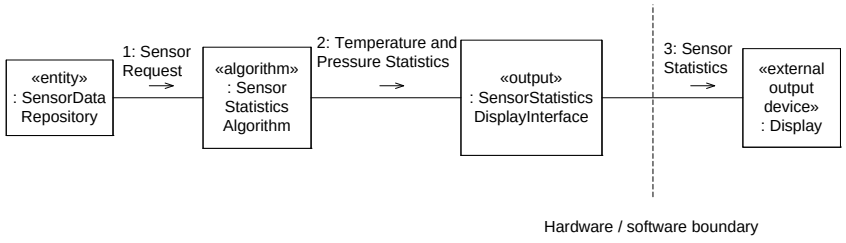
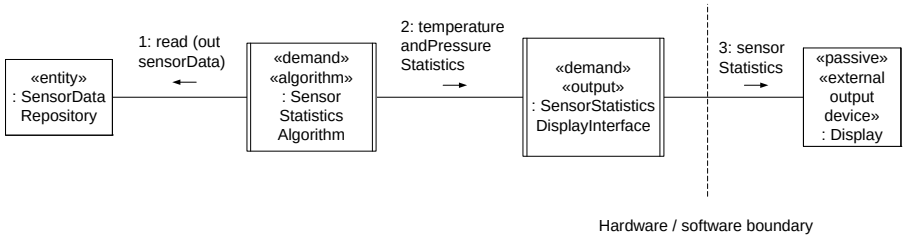


Figure 18.7b Design model – concurrent communication diagram



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Internal Task Structuring Criteria

- Periodic task
  - Task for each periodic activity
- Demand task
  - Task for each demand driven internal activity
- Control task
  - Task executes state machine
- User interaction task
  - Task for each sequential user activity

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Periodic Task

Task for each periodic activity

Task activated periodically

Activated by timer event

Performs activity

Waits for next timer event

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Figure 18.8 Example of periodic task

Figure 18.8a Analysis model – communication diagram

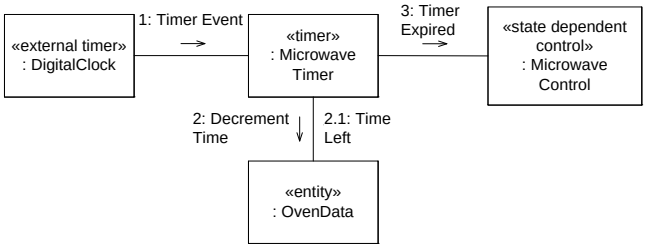
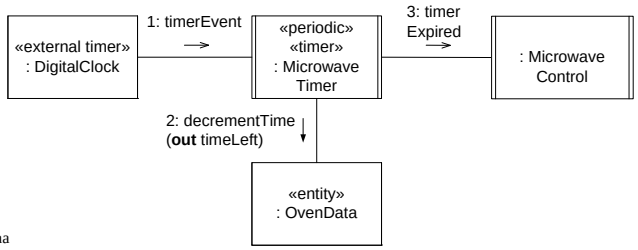


Figure 18.8b Design model – concurrent communication diagram



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Demand Task

- Activity executed on demand
  - Activated by internal event or message
  - Map to Demand Task
- Demand task
  - Activated on demand by event or message sent by different task
  - Performs demanded action
  - Waits for next event or message

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Figure 18.9 Example of demand task

Figure 18.9a Analysis model – communication diagram

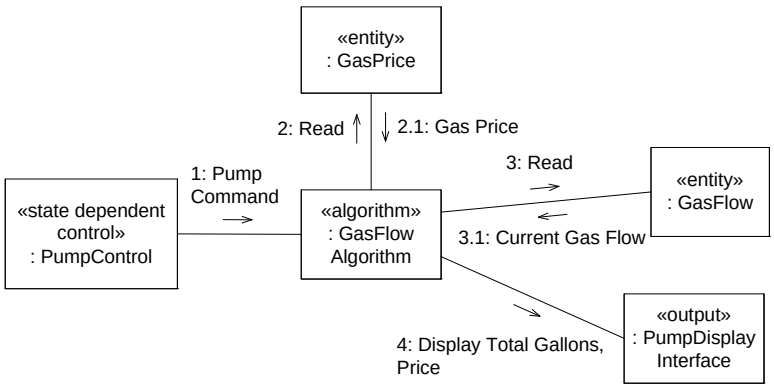

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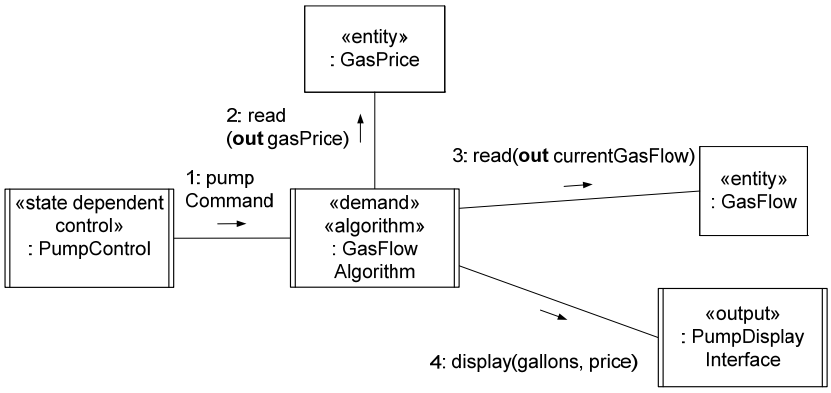
Figure 18.9 Example of demand task

Figure 18.9b Design model – concurrent communication diagram



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Control Task

Task executes statechart

- State dependent control object executes statechart
- Execution of statechart is sequential

One task for each control object

Can have multiple tasks of same type

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Figure 18.10 Example of control task

Figure 18.10a Analysis model – communication diagram

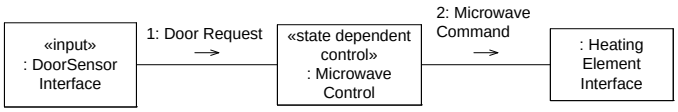
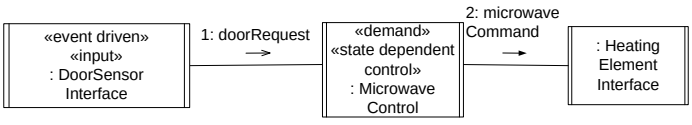


Figure 18.10b Design model – concurrent communication diagram



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User Interaction Task

One task for each sequential user activity

Multi-user system

- One task per user
- User may also spawn background tasks

Windowing system

- User engaged in multiple activities
- Each window executes sequential activity
- One task for each window

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Figure 18.12 Example of user interaction task

Figure 18.12a Analysis model – communication diagram

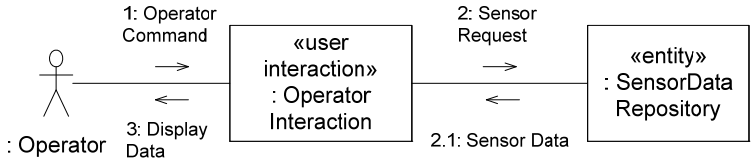

Figure 18.12b Design model – concurrent communication diagram

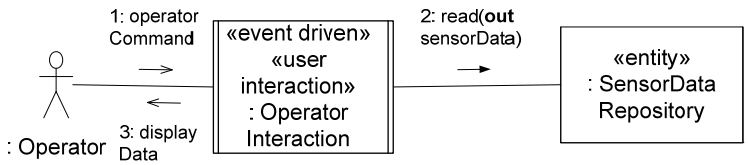

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Figure 18.12 Example of user interaction task

Figure 18.12c Design model – concurrent communication diagram

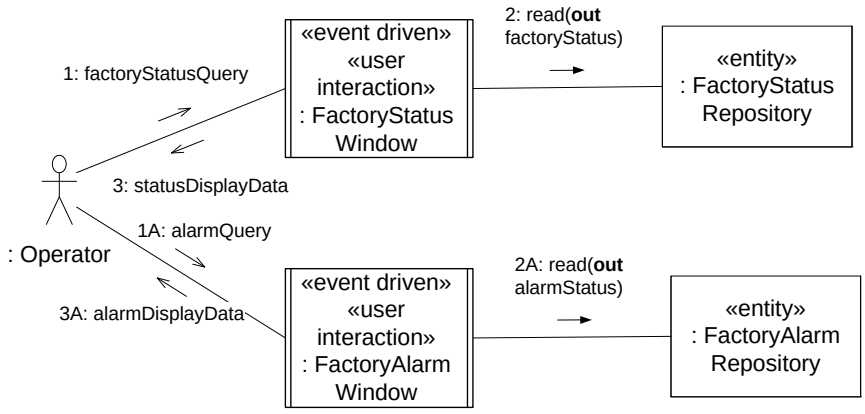

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Figure 21.25 Integrated communication diagram for ATM Client subsystem (before task structuring)

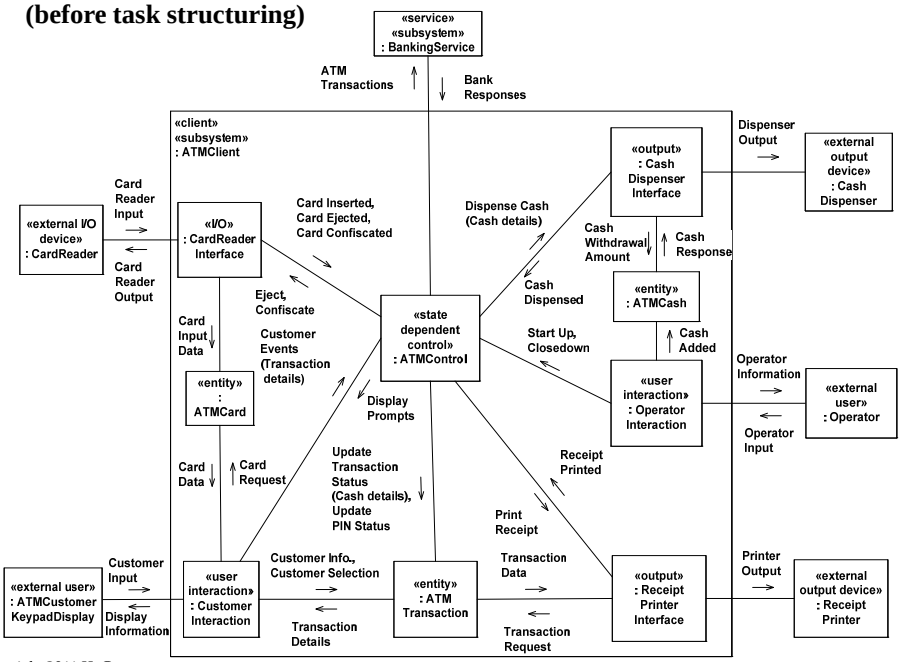

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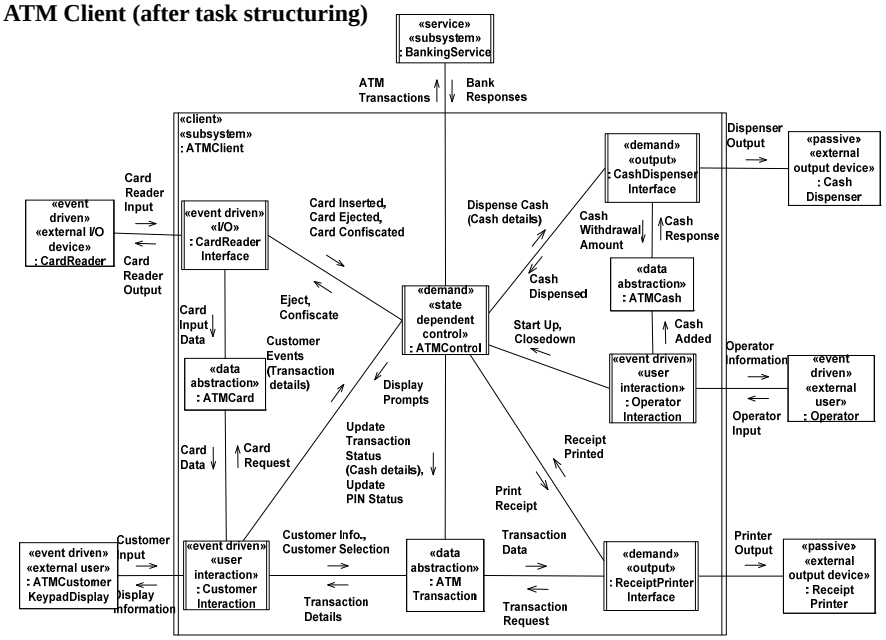
Figure 18.13 Task architecture – initial concurrent communication diagram for ATM Client (after task structuring)



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Banking System Case Study - Task Structuring Criteria

- Event driven I/O task
  - Card Reader Interface
- Demand driven output task
  - Cash Dispenser Interface
  - Receipt Printer Interface
- Event driven user interaction Task
  - Customer Interaction
  - Operator Interaction
- Demand driven state dependent control task
  - ATM Control
- Service task
  - Bank Service

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Define Task Interfaces

- Map Analysis Model simple message interfaces to task interfaces
  - Need to determine type of message communication
- Loosely coupled (asynchronous) message communication
- Tightly coupled (synchronous) message communication
  - With reply
  - Without reply
- Event synchronization
  - External event (interrupt)
  - Timer event
- Passive objects
  - Task interfaces to information hiding object
- Update task architecture

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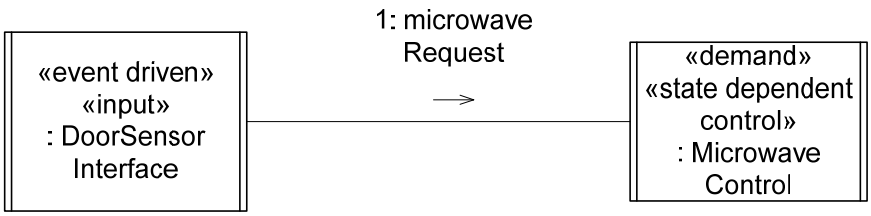
Asynchronous Message Communication (Loosely Coupled)

- Producer sends message and continues
- Consumer receives message
  - Suspended if no message is present
  - Activated when message arrives
- Message queue may build up at Consumer



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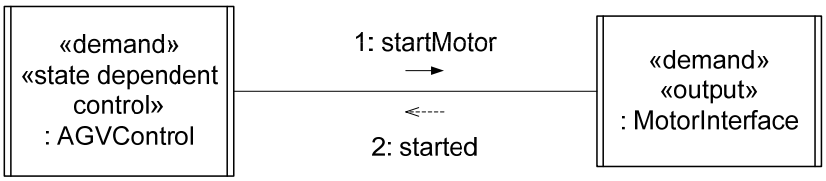
Synchronous (Tightly Coupled) Message Communication With Reply

- Producer task sends message and waits for reply
- Consumer receives message
  - Suspended if no message is present
  - Activated when message arrives
  - Generates and sends reply
- Producer and Consumer continue



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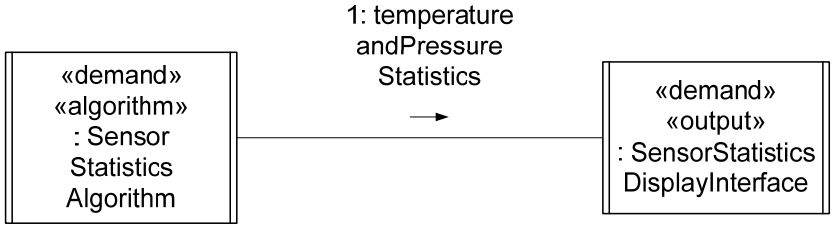
Synchronous (Tightly Coupled) Message Communication Without Reply

- Producer task sends message and waits for acceptance
- Consumer receives message
  - Suspended if no message is present
  - Activated when message arrives
  - Accepts message, Releases producer
- Producer and Consumer continue



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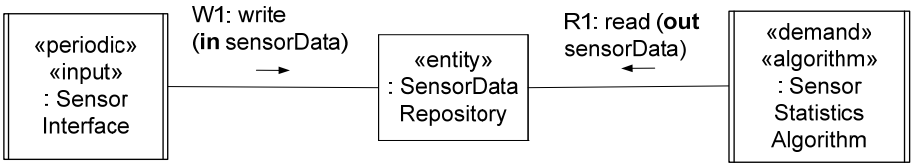
Information Hiding Object

- Passive object
  - Encapsulates data
  - Hides contents of data structure
  - Data accessed indirectly via operations
- Passive object accessed by two or more tasks
  - Operations must synchronize access to data
  - Use semaphore or monitor object
  - Design of class operations is described in Class Design



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Task Interface Specifications (TIS)

Developed during Task Structuring

Expanded during Detailed Software Design

Describes concurrent task's

- Information hidden
- Structuring criteria
- Anticipated changes
- Task inputs and outputs
- Event sequencing logic

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Task Interface Specification

Task interface
- Message communication
  - Type of interface
  - Message names and parameters
- Events signaled
  - Name and Type of event
- External inputs or outputs

Task structure information
- Task structuring criterion used to design task

Task Behavior spec (event sequencing logic)
- Response to each message or event input
- Described informally in Pseudocode

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Example of Task Interface Specification

Name: Card Reader Interface

Information hidden: Details of processing input from and output to card reader.
Structuring criteria: role criterion: input/output; concurrency criterion: event driven
Assumptions: only one ATM card input and output is handled at one time.
Anticipated Changes: Possible additional information will need to be read from ATM card.

Task interface:

Task inputs:
Event input: Card reader external interrupt to indicate that a card has been input.
External input: `cardReaderInput`.
Synchronous message communication without reply:
- `eject`
- `confiscate`

Task outputs:
External output: `cardReaderOutput`
Asynchronous message communication:
- cardInserted.
- cardEjected
- cardConfiscated.

Passive objects accessed: ATMCard
Errors detected: Unrecognized card, Card reader malfunction.

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