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SMA 5508 & MIT 6.883

# Agents

- An agent is an autonomous program.
  - It executes code and can communicate with other agents.
- All the components in a pervasive computing application (whatever that is) usually called agents
  - An agent may be a “proxy” for a device
  - Devices, like camera or keyboards, are controlled by some proxy agent
- Agents may appear or disappear at any time
  - There is some issue in how to start them
  - There can be problems when they crash
    - there may be replicates

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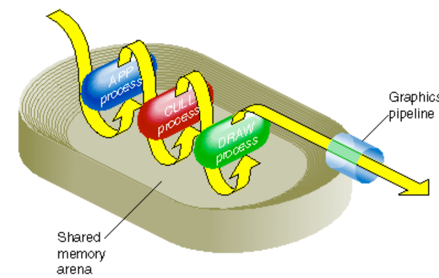
# A collection of agents

- Parallel or distributed programming
  - a bunch of communicating agents working to solve a problem
  - faster
    - two heads better than one
  - geographically distributed
    - everyone can't live together

# Agent communication

- Two main choices:
  - (which was best used to be “religious battle”)
- Shared memory (SM)
  - agents load and store values
    - start with a set of numbers
    - remove two numbers, insert their sum
    - done when only one value remains
  - issues: synchronization, locks, etc.
- Message-passing (MP)

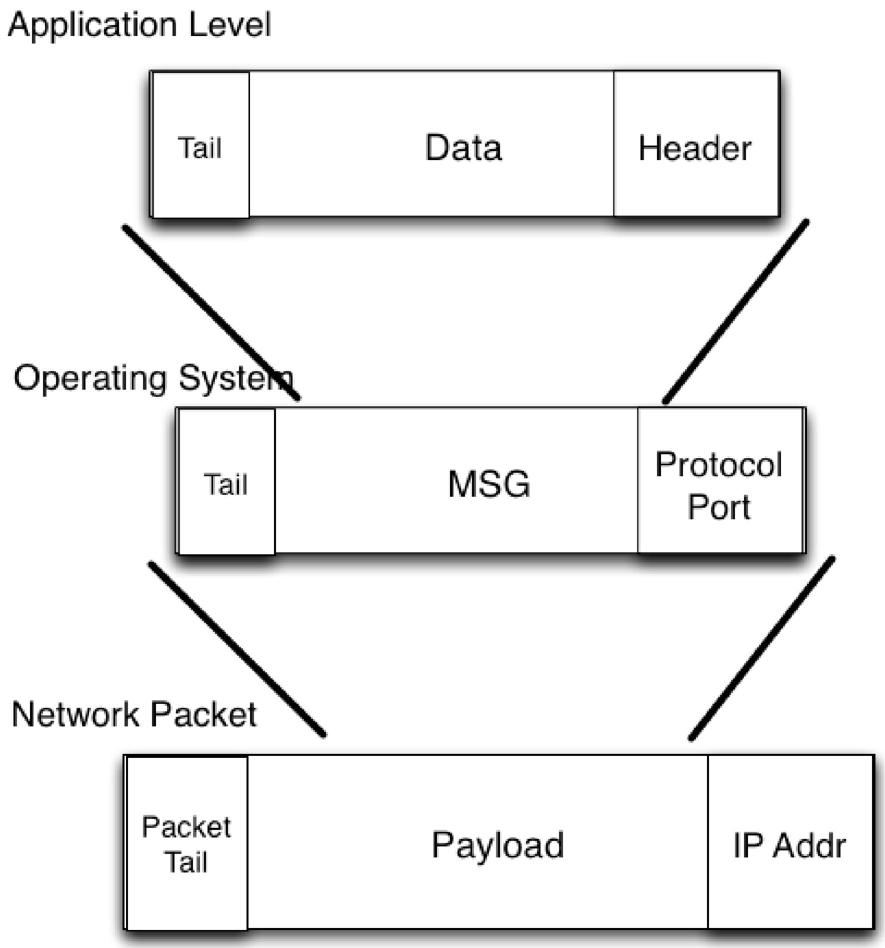




# Agent communication

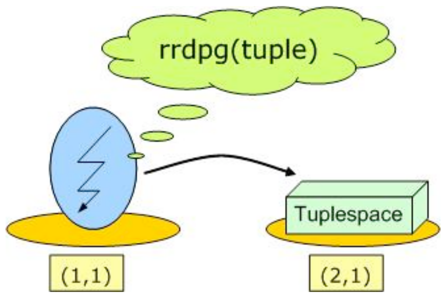
- Message-passing
  - two parts: destination, data
  - Agent Bob: Send(Alice, “Do you want to go out?”)
  - Agent Alice: Recv(from,msg)
    - from = Bob; msg = “do you want to go out?”
    - send(Bob, “No”)
- Issues:
  - Sender must know destination, recv need not
  - blocking or non-blocking
  - low performance, lots of copying of data
- Note: MP can implement SM and vica-versa
  - MP on clusters, SM on multiprocessors


# Message Passing via Sockets

- Sockets are general Application can specify
  - port
  - protocol
  - other attributes
- Message-Passing
  - library does all the specification
  - may reformat data

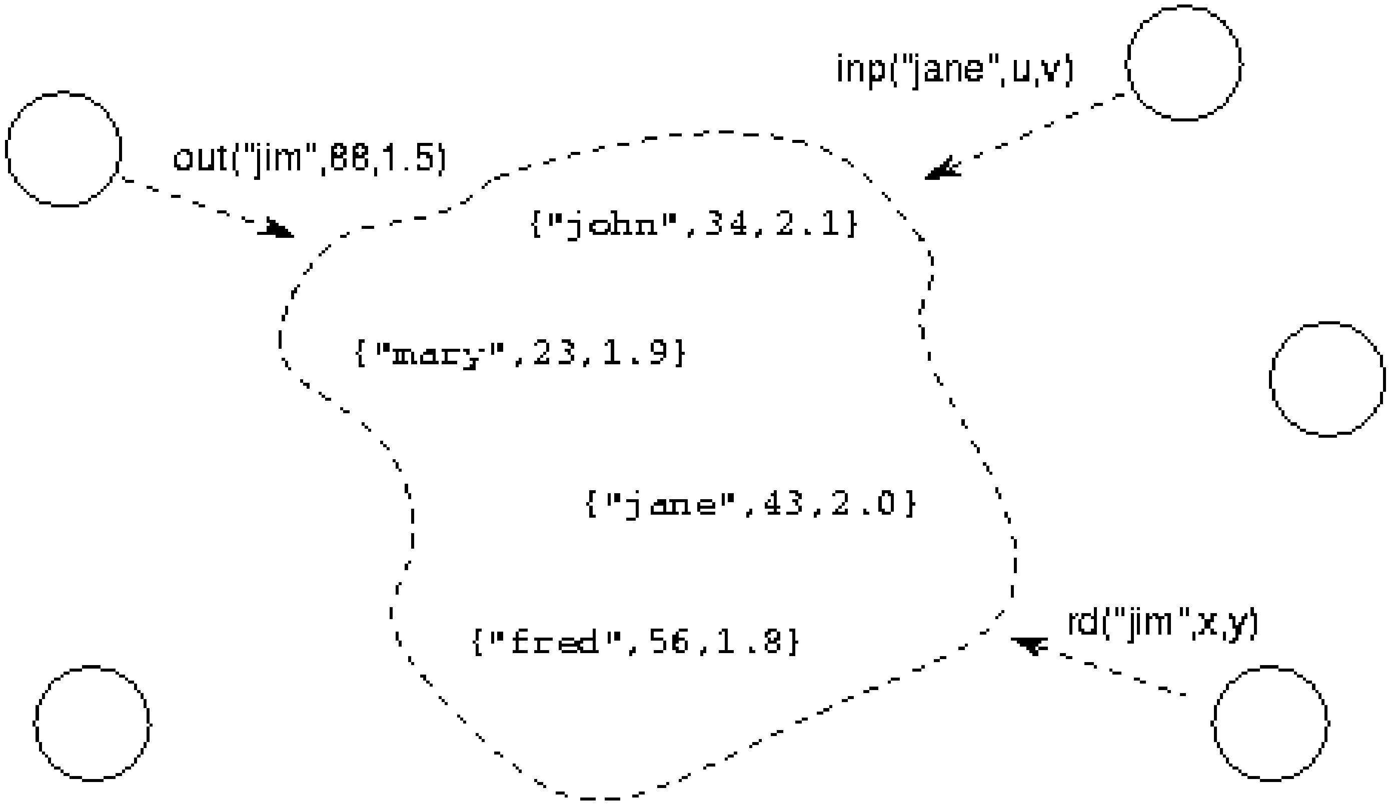


# Tuple-space




- A third communication mechanism!
  - formed basis of Linda programming language
  - tuple: ordered collection of typed elements
- Basic Operations
  - **out**: inserts a tuple, whose fields are either
    - **actual**: a static value
    - **formal**: a program variable
  - **in**: extracts tuple, argument is template to match
    - actuals match fields of equal type and value
    - formals match fields of same type
  - **rd**: same as in, but does not remove matched tuple

# Tuple-space example

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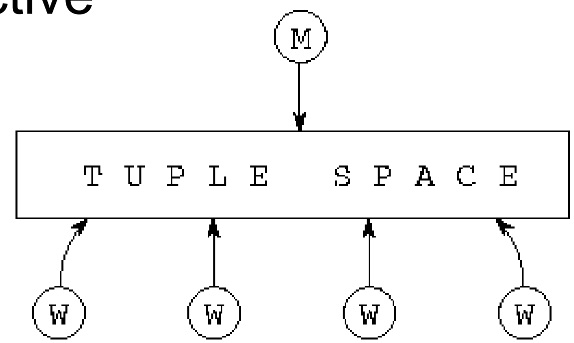
# Linda programming example

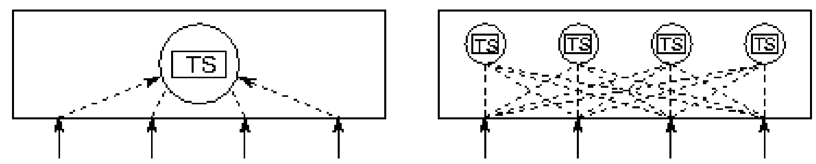
```
procedure manager
begin
  count = 0
  until end-of-file do
    read datum from file
    OUT("datum",datum)
    count = count+1
  enddo
  best = 0.0
  for i = 1 to count
    IN("score",value)
    if value > best then best = value
  endfor
  for i = 1 to numworkers
    OUT("datum","stop")
  endfor
end
```

```
procedure worker
begin
  IN("datum",datum)
  until datum = "stop" do
    value = compare(datum,target)
    OUT("score",value)
    IN("datum",datum)
  enddo
end
```

# What is the big deal?

- Virtual shared memory
  - tuples with [address,value]
  - stores are inserts, loads are non-destructive reads
- Virtual message passing
  - tuples with [dest, data]
  - recv are destructive reads
- Even more, when matching on multiple fields
- Allows many types of implementations



# Agent Interaction Choices

- Direct communication model
  - Jini
  - FIPA
- Indirect, Shared Data-space models
  - EventHeap (centalized)
  - MARS (fully distributed)
- Event-based publish/subscribe models
  - Siena
  - Jini Distributed Events
  - Selective subscription

# Stanford's Event Heap

- Based on Tuple Space paradigm
  - tuple: arbitrary mix of typed fields
  - mechanism for passing data & events
- Extensions make it useful for agents
  - many projects exist based on different extensions

# Event Heap Extensions

- Extended Delivery Semantics:
  - Per-source ordering, always see events in order they are generated by the source
  - Total order:  if tuple space is centralized, get this even if multiple sources
- Persistent Queries:
  - non-destructive read of those matching
  - also matches tuples inserted in future
- Event Notification:
  - like PQ, get notified of future matches
  - at most once semantics

# Need more than simple event heap

While the Event Heap API has proved to be well suited to application development, we believe that it lacks important facilities for constructing many types of Ubiquitous Computing application, as illustrated by the following scenario:

> *Alice, Bob, Joe and Sue are researchers at the University of X. While having lunch at a café, Alice articulates some new ideas regarding project Y. The group decides to use their mobile devices to further explore these ideas using a shared whiteboard application. Each member of the group uses his/her own display and stylus to contribute to the discussion. The individual devices are connected using a wireless ad-hoc network. After lunch, Alice and Joe decide to move to their office and finalise the design. In their office, they resume the discussion from where they left off.*

# Suggested additions

- Need “distributed, replicated or federated local instances
  - (from paper by Storz, Friday, & Davies)
- Multiple event heap instances -- but not easy of implement
  - View: processes that share a view have consistent ordering
  - Session identifiers
    - non-destructive operation on per-session identifier basis
    - can share, copy, or destroy id’s for different semantics

# More general issues

- Lots and lots of middleware systems
  - no winner (may never happen)
- What gets communicated?
  - services, events, XML records
- The shared space is often a:  BROKER
  - The broker stores the tuples and does the matching

# Big Issues

- Naming
  - This is a big, big deal.
  - e.g. how do you name a camera:
    - model brand, IP, DNS name, location, virtual space
    - via attributes (color, 740x1024), ownership?
    - Is there only one name for the agent?
- Matching
  - A big deal
    - Which attributes explicit, which implicit
    - Where to do the lookup?

# Issues

- Addition information provided by broker
  - for services:  how to interface them
  - filtering events
  - higher level events implemented at broker
    - based on multiple basic events
- Adaptivity
  - When to discard services, events
    - keep alive, heartbeats
  - Invoke new instance of service automatically
  - Fault tolerance

# Issues

- Standards
  - XML, SOAP, WSDL
  - Proprietary Interfaces
- Middleware may be new Operating System
  - Whoever controls it will dominate
  - Not clear if there is or will be a winner
- Integration with web-services
  - Lightweight devices are different
  - May want stateful communication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# Tell me about Middleware web comic EPISODE 1 WHAT IS MIDDLEWARE?

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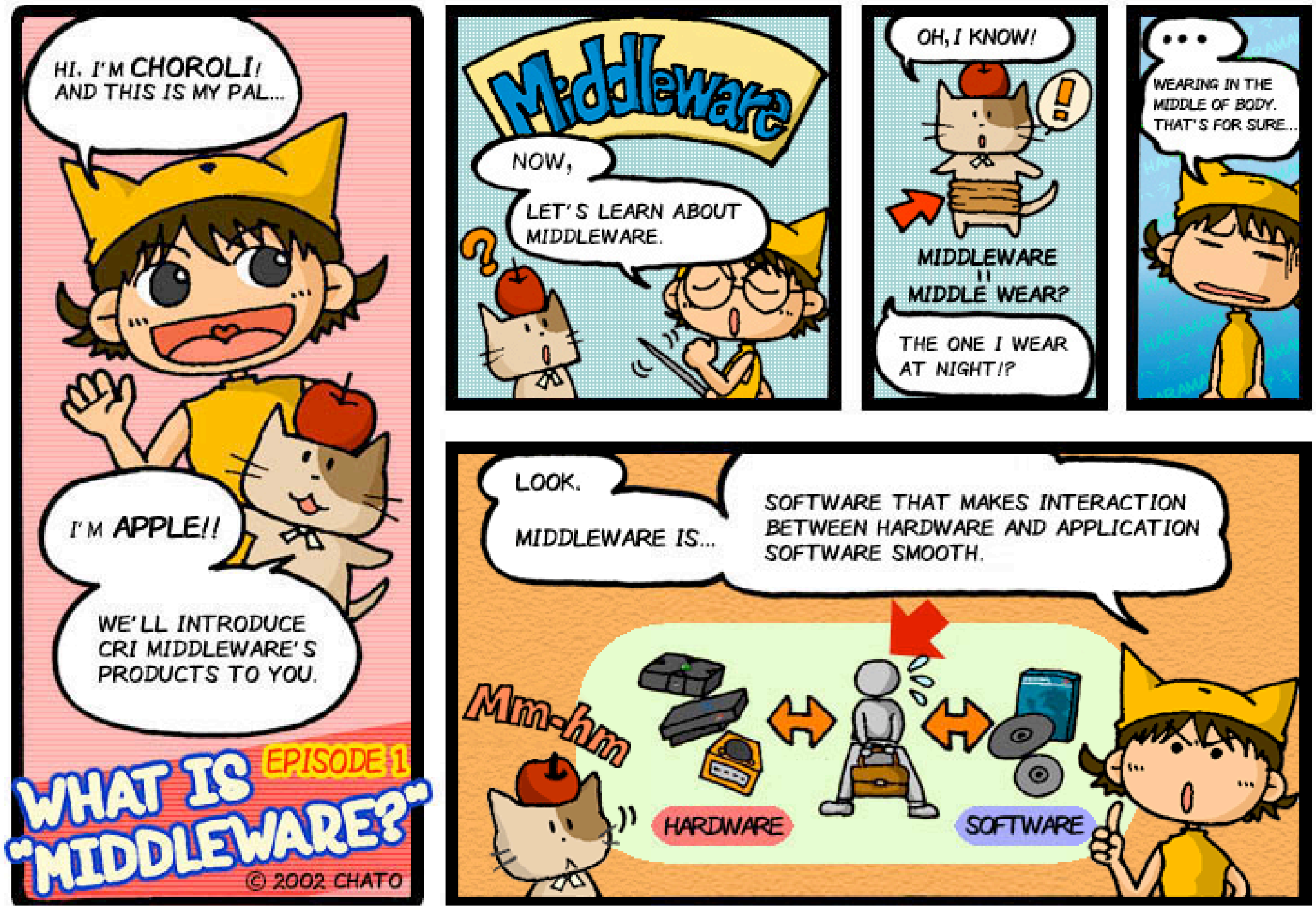
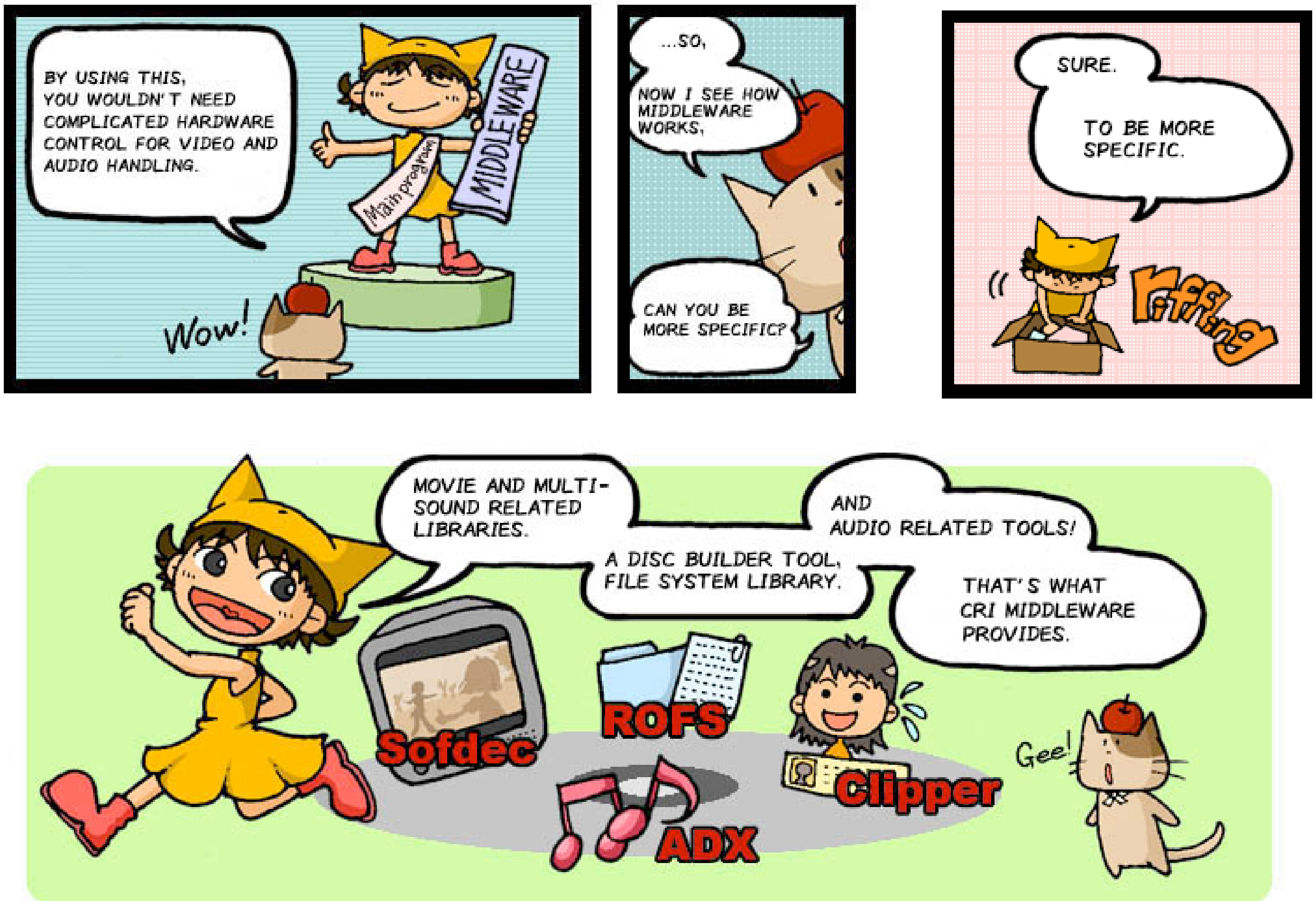
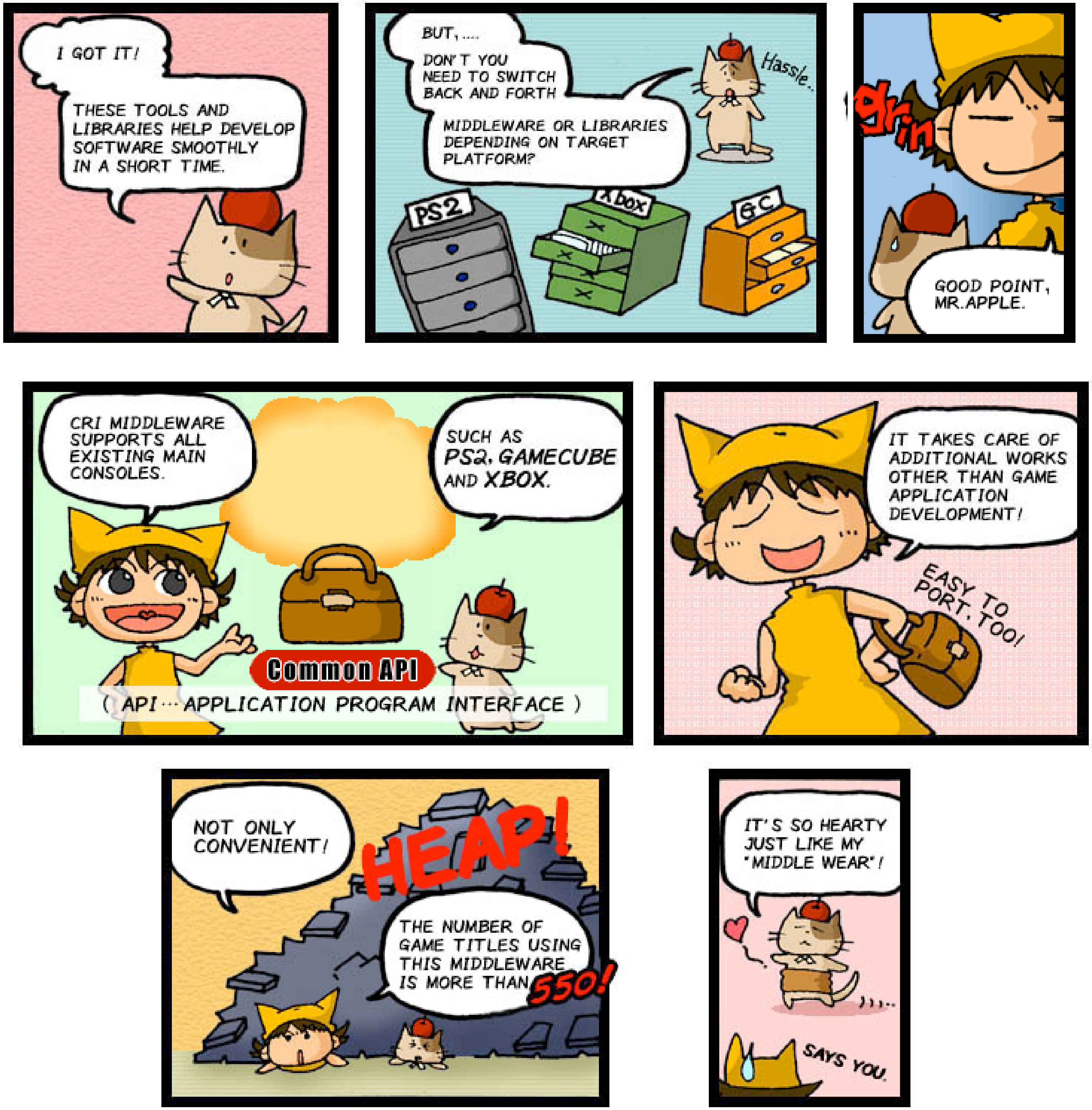



BY USING THIS, YOU WOULDN'T NEED COMPLICATED HARDWARE CONTROL FOR VIDEO AND AUDIO HANDLING.
Main program
MIDDLEWARE
Wow!
...SO,
NOW I SEE HOW MIDDLEWARE WORKS,
CAN YOU BE MORE SPECIFIC?
SURE.
TO BE MORE SPECIFIC.
Riffling
MOVIE AND MULTI-SOUND RELATED LIBRARIES.
A DISC BUILDER TOOL, FILE SYSTEM LIBRARY.
AND AUDIO RELATED TOOLS!
THAT'S WHAT CRI MIDDLEWARE PROVIDES.
Sofdec
ROFS
ADX
Clipper
Gee!


I GOT IT!
THESE TOOLS AND LIBRARIES HELP DEVELOP SOFTWARE SMOOTHLY IN A SHORT TIME.
BUT, ....
DON'T YOU NEED TO SWITCH BACK AND FORTH
MIDDLEWARE OR LIBRARIES DEPENDING ON TARGET PLATFORM?
Hassle..
PS2
Xbox
GC
grin
GOOD POINT, MR.APPLE.
CRI MIDDLEWARE SUPPORTS ALL EXISTING MAIN CONSOLES.
SUCH AS PS2, GAMECUBE AND XBOX.
Common API
( API … APPLICATION PROGRAM INTERFACE )
IT TAKES CARE OF ADDITIONAL WORKS OTHER THAN GAME APPLICATION DEVELOPMENT!
EASY TO PORT, TOO!
NOT ONLY CONVENIENT!
HEAP!
THE NUMBER OF GAME TITLES USING THIS MIDDLEWARE IS MORE THAN 550!
IT'S SO HEARTY JUST LIKE MY "MIDDLE WEAR"!
SAYS YOU.