Analytic Workflow: From Images to Reports

Kevin O’Donnell
Toshiba Medical Research Institute - USA, Inc.
Sr. R&D Manager

Past Chair, DICOM Standards Cmte
Member, WG6, WG10, WG12, WG21, WG29
Dataflow & Workflow

- RIS
- Acquisition Modality
- Processing Worklist
- UPS Worklist
- Processing Workstation
- Modality Performed Procedure Step (MPPS)
- UPS Events (Subscription)
- Instance Avail. Notif.
- Reporting Worklist
- PACS
- Images
Example “Workitem” Tasks:

- 3D View Generation
- Computer Aided Detection
- Clinical Applications
- Pre-fetching
- Image Routing
- CD Burning
- Image Importing
- …
Add “Create Workitem” & “Push Workflow”
• Request another system to add item to worklist
• Replacement for implicit workflow (“push to a box and hope for the best”)

Simplify Implementation
• GPWL had N:M relation of SPS:PPS
• State diagram was very complex

Add “Cancel Request”

Improve Status/Result Monitoring
• Getting PPS feed was awkward; required configuration and forwarding
A **Workitem** has its attributes grouped into 4 Modules:

- Relationship
- Sched. Task Details
- Progress
- Performed Task Details

(this does not affect processing; just for logical organization)
UPS Workitem Structure

Relationship Module
- Patient demographics
- Admission details
  - Order details
  - Requested Procedure
  - Accession #
  - Reason for Requested Procedure
  - Requesting physician/department
  - etc…
Scheduled Proc. Info. Module
- Priority
- Requested perform/completion time
- Requested resources/location
- Requested Procedure descrip./codes
- Requested Processing parameters
- List of Input data IDs & Location
- Input Data Availability Flag
- etc…
**Progress Module**
- UPS State (Scheduled, In-Progress, Completed, Canceled)
- Progress Status – Numerical (e.g. % complete)
- Progress Status – Description (e.g. Annealing phase complete)
- Contact information for performer (e.g. phone #)
- etc…
UPS Workitem Structure

- Relationship
- Sched. Task Details
- Progress
- Performed Task Details

**Performed Proc. Info. Module**
- Time Performed/completed
- Performing resources/location
- Performed Procedure descrip./codes
- Performed Processing parameters
- List of Output data IDs & Location
- etc…
A UPS Object is managed by one SCP. (It doesn’t move)

**4 SOP Classes** can be used to operate on a UPS object.

Each SOP Class supports a few related operations.

SCU/SCP not *required* to implement all the SOP Classes. Can implement SOP Classes based on the operations it needs.
**UPS Push SOP Class** allows SCU systems to:

* **create (push)** a new worklist item (i.e. instance) on a worklist
* **request cancellation** of a worklist item
**UPS Pull SOP Class**

allows SCU systems to:

* *query* a worklist for matching items
* *get details* for a worklist item
* *take ownership/control (pull)* of a worklist item
* *modify progress/status/result* details for the worklist item
* *finalize* a controlled worklist item as Completed or Canceled.

<table>
<thead>
<tr>
<th>UPS Object</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relationship</td>
</tr>
<tr>
<td>Sched. Task Details</td>
</tr>
<tr>
<td>Progress</td>
</tr>
<tr>
<td>Perf. Task Details</td>
</tr>
</tbody>
</table>
UPS Watch SOP Class allows SCU systems to:

* **query** a worklist for items of interest
* **subscribe/unsubscribe** for change events for **one** worklist item
* **subscribe/unsubscribe** for change events for **all** worklist items
* **get details** for a worklist item
* **request cancellation** of a worklist item
UPS Event SOP Class allows SCU systems to:

* receive change events for worklist items
UPS Interfaces: DIMSE and RESTful

DIMSE (Traditional DICOM Protocol)
- Push/Pull/Watch/Event SOP Classes

RESTful (New Web Protocol)
- UPS-RS Supplement 171 (Public Comment)
- HTTP Interface to UPS Service
- Mostly Request/Response for each DIMSE message
- Uses WebSockets for Events

SCP can serve DIMSE clients & RESTful clients interacting with the same UPS workitems.
UPS Pull Workflow Example

Requester (SCU)
- Create UPS
- Subscribe UPS
- UPS State Event
- Get UPS Contents

Watcher (SCU)
- Subscribe Global
- UPS State Event

Worklist Manager (SCP)
- Query
- Get UPS Contents
- UPS State “In-Progress”
- Set UPS Contents
- UPS State “Complete”

Performer (SCU)
- 3D Workstation

Dashboard System
Give me a list of tasks that need to be done (C-FIND)

I will do that one (N-ACTION Set to IN-PROGRESS)

Record these details in the UPS (N-SET attribute values)

I am finished (N-ACTION Set to COMPLETE)
Push Workflow

Please perform this task
(N-CREATE with these attribute values)

Notify me about progress for that task
(N-ACTION Subscribe)

I have started to do that task
(N-EVENT it is IN-PROGRESS)

I have updated details in the UPS
(N-EVENT)

I am finished
(N-EVENT it is COMPLETE)

Give me the result details of the task
(N-GET these attribute values)
Watch Workflow

No central controller

- Workstation watches flow of N-EVENTs: “System X did A”, “System Y did B”
- Workstation decides “Hmmm, I think I will do C”
- Workstation creates a UPS for itself
- Interested Subscribers are notified of Workstation activity via N-EVENT; N-GET details as needed

Similar to Ad hoc/Unscheduled Tasks

Examples:

- CAD workstation sees N-EVENT that Mammo Acq. is complete; decides to do CAD processing
- Reporting station sees N-EVENT that CAD is complete; decides to queue reading worklist for that study
IHE Post-Acquisition Workflow

- IHE PAWF builds on DICOM UPS

- Essential Profile Features:
  - Worklist managed processing
    - Automated & manual
  - Progress notifications
    - Any interested system (RIS, Billing, Reading Worklist, Dashboard, Analytics)
    - Subscription-based
  - Cancelation requests
    - With reason & contact
  - Hosted applications ("DICOM plugins")
Separate the application from the infrastructure

- **Infrastructure** (Hosting Systems) move and store data & results, and manage workflow
- **Applications** process and analyze that data, and provide results back to the infrastructure

Minimize ‘reinvention of the wheel’.

(See DICOM PS3.19)
Portable applications ‘plug into’ any host that implements the standardized ‘socket’

One App, Many Hosts
Benefits of Application Hosting

Users
• One workstation supports any needed functionality
• Mix and Match applications from multiple providers

IT Administrators
• Tired of changing infrastructure to accommodate new workstations simply to add functionality

Application Developers
• Don’t have to re-write applications for dozens of workstations in the market

Workstation Vendors
• Expand their list of offered applications without development effort
Perform UPS Workitems

• Typical Pull Workflow
  – Query, Claim, Update, Complete

• Input / Output References
  – Local to Performer; Local Image Manager; Other Image Manager

• Hosted applications (plugins)
  – Performer may choose to be a Hosting System
  – Apps may be 3rd party
Create UPS Workitems

- **By Workitem Manager**
  - Internal logic
  - Triggered by DSS/Order Filler scheduling
  - Triggered by Image Manager Data

- **By Workitem Creator**
  - Explicit create request
  - Can be grouped with any relevant system

- **By Workitem Performer**
  - Explicit create request
  - “Unscheduled”/Self-scheduled/Ad Hoc
Monitor UPS Workitems

- **Subscribe / Unsubscribe**
  - Globally or for Individual Workitems

- **Applications/Usage**
  - Schedule subsequent tasks
  - Report progress
  - Bill for performed tasks
  - Populate reading worklist
  - Drive dashboard
  - Analyze dept. performance
  - Claim assigned workitems
Cancel UPS Workitems

- **Workitem Manager**
  - Can directly cancel unclaimed workitems
  - Otherwise notifies Performer

- **Workitem Performer**
  - Cancels at its own discretion

- **Watcher**
  - Waits for Notification task was either Completed or Canceled
Applications
Various co-existing patterns possible

**Top-down**
- Original order invokes full set of UPS
- E.g. Protocol code -> standard processing; dept. policy

**Daisy chain**
- Each step completion triggers next UPS
- Push, Pull & Watch variants

**Ad Hoc Performance**
- Performing system self-schedules own UPS
- E.g. human has initiated processing

**Ad Hoc Request**
- E.g. Radiologist decides additional work-up is required; Reporting system creates UPS
Notifications of processing tasks

• Both pre-planned and ad hoc
• Associate by accession #
• Can monitor UPS creation and completion

Processing outputs = Reporting inputs

• Full set of instances is identified
• Storage/retrieval location identified
• Input Readiness State flag
Billing System = Watcher

- Notifications of processing tasks
- What has (actually) been performed
- What has been canceled
- When was it done
- Linked to patient ID & accession #
- Who ordered it
Possible future Profile

Same worklist model as post-processing

• Scheduled tasks
• Relationship to Patient, Order, Workflow
• Lists of inputs and outputs
• Progress/completion notifications

Linkages between post-acquisition and reporting

• Less falls through cracks
• Record of reported instances
• New data can result in notification to radiologist or scheduling of new reporting task
dicom.nema.org -> The DICOM Standard

- Part 4, Annex CC
- Part 3, C.30
- Part 17, Annex BBB

www.ihe.net -> Technical Frameworks

- (Supplement) Scheduled Workflow.b
- (Supplement) Post-Acquisition Workflow
- and many more…
Reliable Watcher (SCU)
• Problem: SCP might delete a completed UPS before SCU gets needed details
• (e.g. due to Network latency or outage)
• Missing a UPS could prevent Watcher from:
  • monitoring completion
  • extracting details
  • creating subsequent UPS Instances,
  • referencing UPS 1 outputs as UPS 2 inputs

Mechanism
- SCU Sets a Deletion Lock flag during subscription
- SCP can’t delete UPS with outstanding Deletion Locks
- SCU removes Deletion Lock after retrieving final state of UPS
- SCP free to delete UPS after all deletion locks removed
- SCP documents how it handles orphans
UPS are transient but can be locked/logged

- Time scheduled
- Time started
- Time completed
- Even intermediate progress for some tasks

Track various activities

- Image import, special reconstructions, automated processing, QC, image export
If you’ve put it In-progress

• Cancel your workitem &
• Create a replacement workitem
  (copy the details from the original)

Alternatively (trickier)

• Communicate the Transaction ID (“secret key”) to the system that is taking over.
Use cases will drive configuration parameters

- Codes for work tasks (RadLex, DICOM, Site, …)
- Object types to be provided as input and as output
- Names of worklists managed by worklist manager

*Profiling = Use case driven specification of use of standards*

- First example is Radiotherapy, DICOM Part 17 Annex BBB
Deployment

Supported in some toolkits & open source

Radiotherapy
- Incorporated in IHE RO Profiles
- Released in Products (see IHE Integration Statements)

Radiology