TRANSPARENT DATA ACCESS AND FILTERING IN THE REGIONAL SIMULATION MODEL (RSM)

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Abstract The Regional Simulation Model (RSM) is an integrated hydrological model which provides generalized, internal data-processing on hydrological, or process control state variables through the use of filters and assessors. Filters and assessors provide a useful and flexible information processing toolset that allows the modeler to easily pre-process, evaluate, modify and coordinate hydrologic or control state variables within the model. The processed variables can be applied within the model as synoptic inputs to operational control algorithms.

INTRODUCTION

In order to effectively provide watershed management operational decision support, it is useful for hydrologic models which simulate anthropogenic water control structures and policies to provide the ability to encapsulate relevant hydrological state variables in a manner consistent with the input requirements of the model control policies and decisions. However, many leading hydrological models provide a limited resource set for this encapsulation, thereby imposing pre-processing of state information and a level of inflexibility in changing modeled control policies or their inputs.

An alternative is to provide a set of information processing filters within the model which appropriately transform the hydrologic or control process state information. In the Regional Simulation Model (RSM) two classes of information processors known as Filters and Assessors are implemented [SFWMD, 2004] for this purpose. Filters are generic information processors which perform simple data filtering operations such as amplitude modulation (multiplication, division, addition, subtraction), simple temporal or spatial variable statistics, or may act as an accumulator/integrator. An assessor is an information processor intended to provide specialized state variable filtering particular to a managerial decision process. For example, the cumulative flood water runoff for a collection of managed canals and basins can be computed by an assessor. The filters and assessors are implemented in a data-driven architecture, which means that all parameters for the information processors are specified by model inputs. As a result, data preprocessing for operational control decisions are independent of the model executable, the modeler is afforded flexibility in evaluating different information processing schemes without reliance on model code development.

In order to ensure that the access to state variables is implemented in a consistent way across the many different objects which will monitor them, a generalized data interface is provided in RSM. This interface is designated as a data 'monitor'. Monitors provide transparent data

access throughout the model, enabling the modeler to easily modify the flow of state information between hydrologic and operational control processes, as well as to record output of model simulations.

Regional Simulation Model In the RSM, the Hydrologic Simulation Engine (HSE) computes hydrological and hydraulic state information (Σ), while operational policies dictate managerial constraints and objectives (Λ). The hydrological state information, as well as any model input variable, and any operational control information can be functionally transformed by Filters and Assessors (A). The Management Simulation Engine (MSE) then produces water management control signals (χ, μ) which are applied to the hydraulic control structures in order to satisfy the desired constraints and objectives. Figure 1 illustrates this overall cyclic flow of state and management information in the RSM.

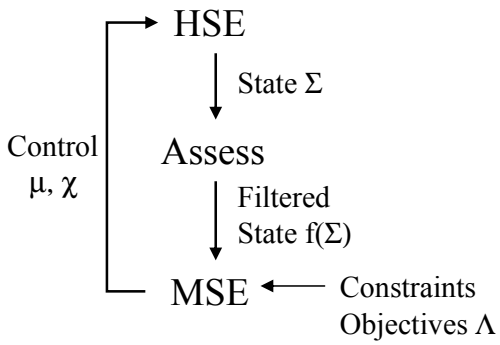

Figure 1: RSM state and management information flow

DATA MONITORS

An important feature of the RSM is the transparent data access available to any process within the RSM. Monitors are a uniform interface between data variables and processes which need access to the variable values. Figure 2 presents a schematic depiction of the data monitor interface in the RSM. For example, if a MSE controller required a canal segment stage value for input, it would simply define the appropriate segment monitor as input to the controller input variable. An illustration of this input declaration in XML would be:

```
<varIn name="Segment1">
    <segmentmonitor id="1" attr="head"/>
</varIn>
```

To change the input data stream for the controller input variable, one simply has to change the XML element `<segmentmonitor>` to the appropriate data source.

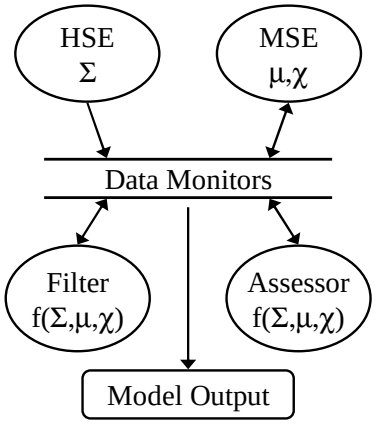

Figure 2: Data Monitor common interface for all RSM state variables

FILTERS

Filters are generic information processors implemented to perform simple, often redundant data filtering operations. For example, a filter may apply a scalar or timeseries amplitude modulation consisting of the usual arithmetic operations (multiplication, division, addition, subtraction) or may compute simple timeseries or spatial variable statistics such as arithmetic, geometric, or other expectations, or may act as an accumulator. The currently implemented RSM filters are described below.

Scale Filter The scale filter applies a scale factor to it's input variable, then passes this new value to the filter output. An example of a division by 2 applied to a canal segment stage is shown below:

```
<filter type="scale" scale="0.5">
   <segmentmonitor id="122" attr="head"/>
</filter>
```

Offset Filter The offset filter simply applies an additive bias term to the filter input. The following example shows a negative one bias applied to a cell water level:

```
<filter type="offset" offset="-1">
   <cellmonitor id="59" attr="head"/>
</filter>
```

Moving Average Filter A moving average filter computes the arithmetic moving average of an input data stream.

```
<filter type="movingavg" numAvg="5">
   <cellmonitor id="7" attr="rain"/>
</filter>
```

Sum Filter The sum filter acts as an accumulator. The number of points to include in the accumulation is specified, once this number of points has been fed into the filter the accumulation buffer is shifted in a FIFO fashion.

```
<filter type="sum" numSum="12">
   <segmentmonitor id="348" attr="head"/>
</filter>
```

ASSESSORS

The role of assessors in the MSE is to perform specialized data preprocessing required for operational control decisions. By decoupling the conditioning and filtering of state and process information from the decision making algorithms, the decision processors can be simplified and modularized. Therefore, an assessor is a information processor intended to provide specialized aggregation or differentiation of state variables particular to a managerial decision process.

For example, the water supply needs (WSN) assessor estimates the volumetric flow in a canal water control unit which is required to meet a downstream water supply demand. This assessor considers both upstream and downstream supply & demand from connected water control units. Once this assessment is completed, a supervisory algorithm can synthesize information from other assessors or operational constraints to arrive at a control decision. Since the supervisor is not concerned with the particulars of how the assessments are made, only with their results, the management algorithms are isolated to information processing relevant to the decision process, and do not include code or rules to perform data filtering and assessment.

IMPLEMENTATION EXAMPLES

The RSM implements a unified design approach for monitors, filters, and assessors based on object oriented design principles. As a result, the interfacing of these constructs from the user's perspective is particularly simple, and powerful. Assessor and filters operate in a piped FIFO fashion, as exemplified by the XML fragments below and in figure 3.

```
<WcuAssessor asmtID="101" name="Reach1" mode="wsneeds">
   <target> <dss file="Reach1Target.dss"/> </target>
</WcuAssessor>

<filter type="offset">
   <offset><dss file="Reach1Offset.dss"/></offset>
   <filter type="MovingAvg" numAvg="15">
      <assessormonitor id="101" attr="flow"></assessormonitor>
   </filter>
</filter>
```

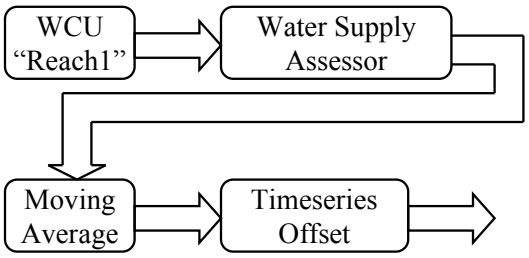

Figure 3: Unified interfacing of data preprocessors allows piped operations.

The first XML section defines a water control unit assessor (WcuAssessor) attached to the canal unit `Reach1`. The assessor is in water supply needs mode, which computes the flow required in the control unit to satisfy the target levels specified in the timeseries file `Reach1Target.dss`. The second XML section defines a dual-stage filter applied to the flow values computed by the WcuAssessor. An assessormonitor is used to reference the assessed flow, and serves as input to a moving average filter. The output of the moving average filter is input to an offset filter, with offset values specified by the timeseries `Reach1Offset.dss`. To change the data source, order, or type of operations, one simply reconfigures the XML specification. This procedure can be automated with the use of a graphical user interface software application.

CONCLUSION

As the complexity of water resource engineering applications grow, a similar increase in the complexity of conjunctive hydrological models capable of integrating natural and anthropogenic influences on watershed response is inevitable. One of the difficulties encountered in such complex, integrated models is the dependence of operational control processes on synoptic aggregations of both hydrological and operational control state variables. To address these issues, the RSM has implemented a data monitoring facility which allows the modeler to access any model state variable with a simple XML input specification. Since the monitor is a generalized feature which reports the appropriate state variable based on the specific invocation (polymorhpism), the complexities of accessing different data sources and formats is hidden from the user.

Once the desired state variables are available, there may be transformations required on them to satisfy the input requirements of operational control processes. The RSM implements a generic class of Filters which is intended to provide simple data scaling, bias, and aggregation. In addition, there may be specialized data processing required for specific control scenarios, this is addressed with Assessors. By adhering to uniform data interfaces and object-oriented methodologies, the monitors, filters and assessors can all interoperate and seamlessly share data.

A result of these data handling abstractions and interfaces is the desired decoupling of state variable processing from managerial decision processing. The data processing is based on a

flexible, data driven specification which is easily modified providing a level of plug-and-play functionality not commonly found in conjunctive hydrological models.

References

[SFWMD, 2004] Regional Simulation Model (RSM) User's Manual, Management Simulation Engine (MSE) Supervisors, South Florida Water Management District, Model Development Division (4540), 3301 Gun Club Road, West Palm Beach, FL March 2004