

ARMLIB 0.1 File Format

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1 Introduction

This file describes a file format for instances to the Area Restriction Model (ARM) [1]. This file format is designed to avoid ambiguity in the definition of the instances and to promote the sharing of test problems. The format distinguishes between *DataSets* and *Instances*. A Data Set includes the adjacency and stand attributes for a given forest and an Instance describes details of an ARM problem such as what periods and harvest scheduling constraints are considered.

2 ARM Data Set

An ARM Data Set consist of adjacency information and a list of stand attributes.

2.1 Stand Attributes

We represent the stands of a forest by means of a set $V = \{1, \dots, n\}$, where n is the number of stands in the forest. Let T represent the number of time periods considered. Each time period will be represented by an index, which is numbered from one. It is assumed that consecutive time periods are distant from each other by a constant Y years. That is, time period 1 corresponds to year 1, time period 2 corresponds to year $1 + Y$, and time period 3 corresponds to year $1 + 3Y$, etc. To each stand we associate attributes as follows:

- a_v area of the stand v .
- $p_{v,t}$ profit obtained if the stand v is harvested in time period t .
- $\alpha_{v,t}$ volume of timber obtained if stand v is harvested in time period t .
- g_v initial age of the stand associated to v (measured in years).

The following subsections define the format of the files in which these attributes are stored. The symbol $\square$ denotes a space in all the file formats.

2.1.1 Area File

It is assumed that area files end with the extension **.area**. The file format is:

```
 $n$   
 $1 \sqcup a_1$   
 $2 \sqcup a_2$   
 $\cdot$   
 $\cdot$   
 $\cdot$   
 $n \sqcup a_n$ 
```

Format 1: Format of area files

2.1.2 Profit File

It is assumed that profit files end with the extension **.profit**. The format is:

```
 $n$   
 $T$   
 $1$   
 $p_{1,1} \sqcup p_{1,2} \sqcup \dots \sqcup p_{1,T}$   
 $2$   
 $p_{2,1} \sqcup p_{2,2} \sqcup \dots \sqcup p_{2,T}$   
 $\cdot$   
 $\cdot$   
 $\cdot$   
 $n$   
 $p_{n,1} \sqcup p_{n,2} \sqcup \dots \sqcup p_{n,T}$ 
```

Format 2: Format of profit files

2.1.3 Volume File

It is assumed that volume files end with the extension **.volume**. The format is:

```

n
T
1
 $\alpha_{1,1} \sqcup \alpha_{1,2} \sqcup \dots \sqcup \alpha_{1,T}$ 
2
 $\alpha_{2,1} \sqcup \alpha_{2,2} \sqcup \dots \sqcup \alpha_{2,T}$ 
.
.
.
n
 $\alpha_{n,1} \sqcup \alpha_{n,1} \sqcup \dots \sqcup \alpha_{n,T}$ 

```

Format 3: Format of volume files.

2.1.4 Age File

It is assumed that age files end with the extension `.age`. The format is:

```

n $\sqcup$ Y
1 $\sqcup$ g1
2 $\sqcup$ g2
.
.
.
n $\sqcup$ gn

```

Format 4: Format of age files.

Note that the number of years per period Y is defined in this file. Furthermore, note that an age equal to -1 denotes that the stand should not be considered in any constraint that uses age information.

2.2 Adjacency Information

For each stand $v \in V$ let $N(v)$ represent the set of stands which are adjacent to v . Observe that there could be many different definitions of adjacency by which to define $N(v)$.

2.2.1 Adjacency File

It is assumed that adjacency files always end with extension `.adjacency`. We assume that for $v \in N$ that $N(v) = \{u_{v,1}, \dots, u_{v,|N(v)|}\}$. The format is:

```

n
1⊔|N(1)|
u1,1⊔u1,2⊔...⊔u1,|N(1)|
2⊔|N(2)|
u2,1⊔u2,2⊔...⊔u2,|N(2)|
.
.
.
n⊔|N(n)|
un,1⊔un,2⊔...⊔un,|N(n)|

```

Format 5: Format of adjacency files

3 Instances

The parameters that determine an instance are:

1. A Data Set.
2. An adjacency file.
3. An area file.
4. A maximum area A .
5. A profit file.
6. A list of time periods $\mathcal{T}$.
7. A green-up type.

The Data Set defines the node set V and the directory where all the Data Set files are stored. The adjacency file defines the adjacency relations between stands. The profit file defines the profit attributes of the nodes. The list of time periods $\mathcal{T}$ defines what periods are considered for harvesting. The green-up type defines the type of green-up used for adjacency constraints and is currently assumed to be one.

The parameters that determine an instance are defined in a text file named **name.arm** where **name** is the name of the instance. The format of this file is described in section 3.1.

A solution for an instance is a set $\mathcal{H} = \{H^t\}_{t \in \mathcal{T}}$, where $H^t \subset V$ is the set of stands harvested in period t and such that the following requirements are satisfied:

1. For each $v \in V$ we have that $v \in H^t$ for at most one $t \in \mathcal{T}$.
2. Let $C \subset H^t$ be a contiguous set of nodes. Then $\sum_{v \in C} a_v \leq A$.

An optimal solution for an instance is a solution that maximizes $\sum_{t \in \mathcal{T}} \sum_{v \in H^t} p_{v,t}$. The format of a file containing a solution to an instance is described in section 3.4.

Additionally an instance might include some extra harvest scheduling requirements on the solutions. Harvest scheduling constraints are also included in the `.arm` file and are described in section 3.2

3.1 Basic Instance File Format

In this section we describe the file format of an instance file with `.arm` extension. We also describe the format of the mandatory parameters of the file.

An instance file is a text file where each line contains either a mandatory parameter, a harvest scheduling constraint requirement or a comment. Comment lines start with character `#`, other lines contain a string describing a mandatory parameter or harvest scheduling constraint. In the following subsections we describe the line formats of the mandatory parameters. Again, $\sqcup$ denotes a single space.

3.1.1 Data Set

This parameter describes the data set the instance is based on. The format is

<code>[DataSet] $\sqcup$ FileName</code>

Format 6: Format of Data Set

where `FileName` is the name of the subdirectory where the data set is stored.

3.1.2 Area File

This parameter describes the area file to be used. The format is

<code>[AreaFile] $\sqcup$ FileName.area</code>

Format 7: Format of Area File

where `FileName.area` is the name of the file used for adjacency. This file should be in the subdirectory defined by `[DataSet]`

3.1.3 Adjacency File

This parameter describes the adjacency file to be used. The format is

<code>[AdjFile] $\sqcup$ FileName.adjacency</code>

Format 8: Format of Adjacency File

where `FileName.adjacency` is the name of the file used for adjacency. This file should be in the subdirectory defined by `[DataSet]`

3.1.4 Maximum Area

This parameter describes the maximum allowed clear cut area. The format is

$[\text{MaxArea}] \sqcup A$

Format 9: Format of Maximum Area

where A is a number describing the maximum allowed clear cut area in the same units as the file defined by $[\text{AreaFile}]$.

3.1.5 Profit File

This parameter describes the profit file to be used. The format is

$[\text{ProfitFile}] \sqcup \text{FileName.profit}$

Format 10: Format of Profit File

where FileName.profit is the name of the file used for profit. This file should be in the subdirectory defined by $[\text{DataSet}]$

3.1.6 List of Time Periods

This parameter describes the list of periods to use. The format is

$[\text{TimePeriods}] \sqcup \hat{T} \sqcup \hat{t}_1 \sqcup \dots \sqcup \hat{t}_{\hat{T}}$
--

Format 11: Format of Period List

where $\mathcal{T} = \{\hat{t}_1, \dots, \hat{t}_{\hat{T}}\}$ is the list of periods to use and $|\mathcal{T}| = \hat{T}$. The list $\hat{t}_1 \sqcup \dots \sqcup \hat{t}_{\hat{T}}$ should be strictly increasing.

3.1.7 Green-Up

This parameter describes the green-up used. The format is

$[\text{GreenUp}] \sqcup \Delta$

Format 12: Format of Maximum Area

where Δ is a number describing the green-up used. Currently it is assumed to be one.

3.2 Harvest Scheduling Constraints

This section describes the requirements imposed by harvest shceduling constraints and the format they are described in a instance file with extension `.arm`. For a set of time periods $\mathcal{T}$ let $\text{last}(\mathcal{T})$ be the last period of $\mathcal{T}$. Also for

$t \in \mathcal{T}$ let $\text{next}(t)$ be the next period after t in $\mathcal{T}$. For example if $\mathcal{T} = \{1, 3, 5\}$ we have that $\text{last}(\mathcal{T}) = 5$ and $\text{next}(1) = 3$.

Note that an instance might include more than one harvest scheduling constraints of the same time. For example, an instance could contain a volume flow constraint for hardwood and another for softwood.

3.2.1 Volume Flow Constraints

For a solution $\mathcal{H} = \{H^t\}_{t \in \mathcal{T}}$ volume flow constraints require:

$$\sum_{v \in H^{\text{next}(t)}} \alpha_{v, \text{next}(t)} \geq (1 - L/100) \sum_{v \in H^t} \alpha_{v, t} \quad \forall t \in \mathcal{T} \setminus \{\text{last}(\mathcal{T})\} \quad (1)$$

$$\sum_{v \in H^{\text{next}(t)}} \alpha_{v, \text{next}(t)} \leq (1 + U/100) \sum_{v \in H^t} \alpha_{v, t} \quad \forall t \in \mathcal{T} \setminus \{\text{last}(\mathcal{T})\} \quad (2)$$

where $L, U \in [0, 100]$.

The parameter describing this harvest scheduling constraints is of the form:

`[VolumeFlow]□L□U□volumeFile.volume`

Format 13: Format of Volume Flow Constraint

where `volumeFile.volume` is the file from where the volume attributes $\alpha_{v, t}$ are loaded. This file should be in the subdirectory defined by `[DataSet]`

3.3 Average Ending Age Constraints

For a solution $\mathcal{H} = \{H^t\}_{t \in \mathcal{T}}$ average ending age constraints require:

$$\sum_{v \in \bar{H}^0} a_v(g_v + \bar{N}Y) + \sum_{t \in \mathcal{T} \setminus \{\text{last}(\mathcal{T})\}} \sum_{v \in \bar{H}^t} a_v(\bar{N} - \text{next}(t))Y \geq \bar{G} \sum_{v \in \bar{V}} a_v$$

where $\bar{G} \geq 0$ is the target minimum average ending age, $\bar{N} \geq \text{last}(\mathcal{T})$ is the end of the planning horizon when the average ending age is measured, $\bar{V} = \{v \in V : g_v \geq 0\}$, $\bar{H}^t = \{v \in H^t : g_v \geq 0\}$ and $\bar{H}^0 = \bar{V} \setminus \bigcup_{t \in \mathcal{T}} H^t$ denotes the set of unharvested nodes with non-negative initial age.

The parameter describing this harvest scheduling constraints is of the form:

`[AvgAge]□ $\bar{G}$ □ $\bar{N}$ □ageFile.age`

Format 14: Format of Average Ending Age Constraint

where `ageFile.age` is the file from where the age attributes $g_{v, t}$ and the years per period Y are loaded. This file should be in the subdirectory defined by `[DataSet]`

3.4 Solution Files

We define two types of solution files. The first type of solution file indicated what stands are harvested in each period; we denote this type as the *period based* solution file. The second type of solution files indicates the period in which each stand is harvested; we denote this type as the *stand based* solution file.

Let $\mathcal{H} = \{H^t\}_{t \in \mathcal{T}}$ be a solution for $\mathcal{T} = \{t_1, \dots, t_{|\mathcal{T}|}\}$ with $t_1 \leq t_2 \leq \dots \leq t_{|\mathcal{T}|}$. Lets assume that each for each t $H^t = \{H_1^t, \dots, H_{|H^t|}^t\} \subset V$. In addition, for each stand $v \in V$ let

$$h_v = \begin{cases} t \text{ s.t. } v \in H^t & \text{if } v \in \bigcup_{t \in \mathcal{T}} H^t \\ 0 & \text{o.w.} \end{cases} \quad (3)$$

be the period in which stand v is harvested, with $h_v = 0$ denoting that the stand is not harvested. The period based solution files have a `.sol` extension and their format is:

```
|T| Obj
t1 |H^t1|
H1^t1 H2^t1 ... H|H^t1|
t2 |H^t2|
H1^t2 H2^t2 ... H|H^t2|
.
.
.
t|T| |H^t|T||
H1^t|T| H2^t|T| ... H|H^t|T||
```

Format 15: Format of period based solution files.

where `Obj` is the objective value of the solution.

The stand based solution files have a `.sol.txt` extension and their format is:

```
1 h1
.
.
.
|V| h|V|
```

Format 16: Format of stand based solution files.

References

- [1] A. T. Murray. Spatial restrictions in harvest scheduling. *Forest Science*, 45(1):45–52, 1999.