A. Agent Input-Ouput System (AIOS)

A.1 Agent Class Template

Agents are created from constructor functions providing an ATG behaviour template, shown in Def. 1.

```
function agentclass(p1,p2..) {
     Body Variables
    this.v1 = initial value
    this.v2 = initial value
     Activtites
    this.act = {
        a1: function () { .. },
        a2: function () { .. },
        ..
    }
     Activity Transitions
    this.trans = {
        a1: anext,
        a2: function () { return anext },
        ..
    }
     Signal Handler
    this.on = {
        signal: function (arg) { .. },
        ..
    }
     Current and Initial Activity
    this.next = ainit
}
```

Definition 1. Basic structure of an agent class constructor function

A constructor function defines a set of parameters, body variables, activity and transition function objects, an optional signal handler function object, and the reserved *next* body variable pointing to the current (or after a start the initial) activity.

A.2 AgentJS API

The following sections describe the agent programming interface of *AgentJS*. The operations visible to agents depend on their privilege level. Operations restricted to privilege levels are marked.

A.3 Computation

There are various powerful and extended computational functions that can be used by agents. Please note that for some reason arrays and objects cannot be iterated in agent processes by using the `for(p in a)` statement. Instead the `iter` function has to be used. Furthermore, the `this` object inside function callbacks references always the agent object, i.e., body variables and functions can be accessed by the `this` object.

A.3.1 Operations

abs

```
function(number) → number
```

Returns absolute value of number.

add

```
function(a:number|array|object,
b:number|array|object) → number|array|object
```

General purpose addition operation for scalar numbers, arrays, and objects of numbers.

iter

```
function(object|array, function (@element,@index?))
```

Iteration over object attributes or array elements.

concat

```
function(array|string|object, array|string|object)
→ array|string|object
```

Concatenation operation for arrays, strings, and objects.

contains

```
function(array|object,
(number|string)|(number|string)[]) → boolean
```

Checks existence of an element or an array of elements in an array or object (attribute)

copy

```
function(array|object|string) →
array|object|string
```

Returns a copy of an array, object, or string. The object may not contain cyclic references.

div

```
function(number,number) → number
```

Integer division operation

empty

```
function(array|object|string) → boolean
```

Checks if an object, string, or array is empty ({} [] "")

equal

```
function(number|string|array|object,
number|string|array|object) → boolean
```

Checks equality of numbers, strings, arrays, and objects.

filter

```
function(array|object, function (@element,@index?)
→ boolean) → array|object
```

Filter operation for arrays and objects.

head

```
function(array) → *
```

Returns head (first) element of array.

int

```
function(number) → number
```

Returns integer number.

isin

```
function(array|object,
number|string|(number|string)[]) → boolean
```

Checks existence of an element in an array or object (attribute). The element can be an array, too.

iter

```
function(array|object, function (@element,@index?))
```

Iterator for arrays and objects.

length

```
function(array|object|string) → number
```

Returns length of an array, object or string.

map

```
function(array|object, function (@element,@index?)
→ *|none) → array|object
```

Map and filter operation for arrays and objects. If the user function returns undefined the element is discarded.

matrix

```
function(@cols, @rows, @init) → [] array
```

Create a matrix (array of arrays).

max

```
function(a:number|array, b?:number) → number
```

Returns largest number from two numbers or from array of numbers.

min

```
function(a:number|array, b?:number) → number
```

Returns smallest number from two numbers or from array of numbers.

neg

```
function(number|array|object) →
number|array|object
```

Returns negative number, array or object of numbers.

random

```
function(a:number|array|object, b?:number,
frac?:number) → number|*
```

Returns a random number from the interval [a,b] or an element from an array or object. The optional fraction parameter specified the rounding precision (frac=1 return integer numbers).

reverse

```
function(array|string) → array|string
```

Reverses elements of an array or string.

sort

```
function(array, function (@element1,@element2) →
number) → array
```

Sorts an array by a user function returning {-1,0,1} numbers. Descending order is reached if a<b return a positive value, otherwise if a negative value is returned an ascending order is reached.

sum

```
function(array|object, map?:function) → number
```

Returns the sum of elements of an array or attribute values of an object. The optional user mapping function can be used to return a computed

value for each element.

string

```
function(*) → string
```

Returns string representation of argument.

tail

```
function(* array) → *
```

Returns tail (last) element of array.

zero

```
function(number|array|object) → boolean
```

Checks if a number, all elements of an array or all attributes of an object are zero.

A.3.2 Examples

```
this.a=[1,2,3];
this.o={real:2.0,img:3.1};
this.sq = function (objORarray) {
  var res=0;
  iter(objORarray,function (elem,index) {
    res=res+elem*elem;
  });
  return res;
}
..
    var x,y,z;
    x=this.sq(a); // x==14
    y=this.sq(o); // y==13.61
    z=sum(a);     // z==6
    if (zero(this.o)) this.o={real:1.0,img:1.0};
..
```

Usage of computational functions and user defined functions assigned to agent body variables.

A.4 Environment

info

```
function (@kind) → {}
```

Return environmental information. Supported information requests are:

```
 typeof @kind = 'node' | 'version' | 'host'
```

The node information request returns:

```
{id        : id string,
 position : {x:number, y:number},
 location : undefined | {lat:number, lon:number},
 type      : string}
```

The node type is a string identifier from the set:

```
 typeof  type  =  {'shell',  'webshell',  'relay',
'webapp', 'mobileapp'}
```

The host information request returns information about the host platform:

```
{type:string='node' | 'browser'}
```

myClass

```
function () → string
```

Returns the class of the agent (if known). Same result is returned by accessing the `this.ac` variable.

myNode

```
function () → string
```

Returns the identity name of the current JAM node.

myParent

```
function () → string
```

Returns the identity name of the parent agent of this agent (if any).

me

```
function () → string
```

Returns the identity name of this agent.

clock

```
function (ms:boolean) → number|string
```

Returns current system clock in milliseconds (*ms* argument is true) or in time format `HH:MM:SS`.

A.5 Tuple Space

Tuple spaces are data bases storing vectors of values. Each tuple has a dimension (the number of values) and a type interface. Tuples can be read or consumed by using patterns. Patterns are like tuple but allowing wildcard values (none). If there is no matching tuple found in the data base, the agent is suspended until a matching tuple arrives or a timeout occurs (by using the `try_*` operations). Since JavaScript programs cannot block, a callback function has to be provided and the blocking operation must be placed at the end of an activity or inside a scheduling block. Commonly the first value of a tuple (a string) is used as a key, but this is only a weak constraint that has not to be satisfied. If the first value is a string it is used as a hash key in the tuple data base speeding up tuple pattern matching. A tuple space has a linear structure and is non-persistent. To support complex hierarchical data bases, *JAM* provides a SQLite data base server and access to this data base for level 3 agents (see section A.13). Tuple spaces can be mapped on tables in this SQL data base (by tuple space provider and consumer functions passed to JAM).

A.5.1 Types

```
type tuple =
   (number|string|boolean|array|object) []
type pattern =
   (number|string|boolean|array|object|null) []
```

A.5.2 Examples

```
out(['MARKING1',1]);
out(['SENSORA',100,true]);
inp(['SENSORA',_,_],function (tuple) {
  if (tuple) this.s =tuple[1];
});
rm(['SENSORA',_,_],true);
try_rd(0,function (tuple) { .. });
ts(['MARKING',_],function (t) { t[1]++ });
alt([
  ['SENSORA',_,_],
  ['SESNORB',_],
  ['EVENT'],
  ],function (tuple) {
    if (tuple && tuple[0]=='EVENT') {..}
    else ..
  });
```

Example 2. Tuple Access

A.5.3 Operations

alt[1,2,3]

```
function(pattern [], callback:function,
all?:boolean, tmo?:number)
```

Input operation with multiple search patterns that can have different type signatures and arities. The first tuple matching one of the pattern is consumed and passed to the callback function. If there are multiple tuples matching a specific pattern and the flag is set than all matching tuples are consumed and returned.

collect[1,2,3]

```
function (to:path, pattern) → number
```

The collect operation moves tuples from this source TS that match template pattern into destination TS specified by path `to` (a node destination).

copyto[1,2,3]

```
function (to:path, pattern) → number
```

Copies all matching tuples form this source *TS* to a remote destination *TS* specified by path `to` (a node destination).

evaluate[1,2,3]

```
function (pattern, callback:function (tuple|none))
→ tuple
```

Access an evaluator tuple created by a `listen` operation. The evaluator evaluates the given pattern to a tuple and passes the tuple back to the call-back function of the requesting agent.

exists[1,2,3]

```
function (pattern) → boolean
```

Check if a tuple matches the given patterns.

inp[1,2,3]

```
function (pattern, callback:function, all?:boolean,
tmo?:number)
```

Consumes a tuple matching the given pattern that is passed to the callback function. If there are multiple tuples matching a specific pattern and the `all` flag is set than all matching tuples (array) are consumed and returned. If there is no matching tuple and `tmo` is zero (immediate reply) or positive (timeout) than the callback handler is called with a none value argument.

listen[1,2,3]

```
function (pattern, callback:function (pattern) →
tuple)
```

Install a tuple evaluator (active tuple) that can be accessed by the `evaluate` operation.

out[1,2,3]

```
function (tuple)
```

Store a tuple in the data base.

mark[1,2,3]

```
function (tuple, tmo:number)
```

Store a tuple with a limited lifetime in the data base.

rd[1,2,3]

```
function (pattern, callback:function, all?:boolean,
tmo?:number)
```

Read a tuple matching the given pattern that is passed to the callback function. If there are multiple tuples matching a specific pattern and the `all` flag is set than all matching tuples (array) are read. If there is no matching tuple and `tmo` is zero (immediate reply) or positive (timeout) than the callback handler is called with a none value argument.

rm[1,2,3]

```
function (pattern, all?:boolean)
```

Remove a tuple or if the `all` flag is set all matching tuples from the data base.

store[1,2,3]

```
function (to:path, tuple) → number
```

Stores a tuple in a remote TS specified by path `to` (a node destination). Returns number of stored tuples.

ts[1,2,3]

```
function (pattern, callback:function(tuple) →
tuple)
```

Atomic and non-blocking test-and-set operation that can be used to modify a tuple in place found based on the provided pattern.

alt.try, inp.try, rd.try, evaluate.try[1,2,3]

```
function (tmo:number, ..)
```

Try operation and execute an alternation, input, or read operation with a given timeout (Milliseconds). **If there was no matching tuple found and the timeout elapsed the callback is fired with a null argument, followed by the continuation of the agent execution with the next activity.**

```
rd.try(timout,tuple,function (t) {
  if (t) this.data=t,log('GOTIT');
  else log('DONT GOTIT');
})
```

A.5.4 Active Tuples

Passive tuples are produced via the `out` operation and consumed via the `rd` and `inp` operations. Among passive tuples, there are active tuples that are evaluated by a consumer and passed back to the original producer (bidirectional tuple exchange) by using the `listen` and `evaluate` operations.

```
listen(pattern, function (tuple) {
  Modification of tuple: Replace formal
  with actual parameters
  return tuple'
})
evaluate(pattern, function (tuple) {
  Process evaluated tuple
})
```

Definition 3: Active Tuple Template

A.6 Signals

Signals are used as a low-level inter-agent communication. In contrast to tuple, signals can be send directly to specific agents. Although there are remote tuple space operations, signals should be used for remote agent communication. Signals can carry an argument (data). The delivery of signals is only reliable if the source and destination agents are processed on the same platform node. If the destination agent is processed on a remote platform the signals are delivered as messages to the destination node along the travel path of the destination agent.

There is no agent localisation, and only agent traces are used to deliver a signal to a remote agent, i.e., each node remembers the direction/link an agent used to migrate to another node. Therefore, remote signals can only

be send to agents that were previously processed on the node of the source agent! To enable back propagation of signals, each node remembers the direction/link of incoming signals and its source agent, too. The entries of these trace caches have a timeout and are removed automatically. Each time a signal is propagated along the trace path of an agent, the cache entries of all path nodes are refreshed. After a timeout of a trace cache entry, signals cannot be delivered to an agent along a path using this node!

A signal can be received by an agent by installing a signal handler in the `this.on` section of the agent class.

The destination agent is specified by the agent identifier. Usually agent identifiers should not made be public for security reasons (An agent at least with privilege level 1 can control another agent on the same node if it knows its agent identifier). Hence, signals are often used between parent-child agents. Each child knows the agent identifier of its parent, and vice versa.

Signals should carry only simple arguments. Objects may not contain cyclic references. Complex data structures should only be exchanged between agents by using the tuple space.

A.6.1 Template

The following code template shows agent communication via signals between a parent and its created child agents (using forking). The child agent is created in activity *a1*. After the agent process forking, both agents continue with activity *a2*.

```
// Template
this.child=none;
this.act = {
  a1: function () {
    // Create child agent
    this.child=fork();
  }
  a2: function () {
    // Raise signal
    if (this.child)
      send(this.child,'PARENT','Hello World');
  }
```

```
}
this.trans = {
    a1:a2
}
// Installation of signal handlers
this.on : {
  'PARENT' : function (arg,from) {
    log('Got message '+arg+' from '+from);
  }, ..
}
```

A.6.2 Types

```
// Type definitions
type aid = string
type range =
    hops:number |
    region:{dx:number,dy:number,..}
```

A.6.3 Operations

send[1,2,3]

```
function (to:aid, sig:string|number, arg?:*)
```

Sends a signal @sig (string or number) to an agent with identification string @to with an optional argument @arg.

broadcast[1,2,3]

```
fucntion (class:string, range, @sig, @arg?)
```

Broadcasts a signal to multiple agents of class @class with the specified range.

sendto[1,2,3]

```
function (to:dir, sig:string|number, arg?:*)
```

Sends a signal @sig (string or number) to a remote node specified by @to with an optional argument @arg. If there is an agent on the remote

node handling the specific signal it will be passed to the listening agent.

sleep

```
function (tmo:number)
```

Suspends an agent for a specific time. If @tmo is zero, the agent is suspended until it will be woken up by another agent using the wakeup operation.

wakeup

```
function (aid?:string)
```

Wakes up a sleeping agent. Can be called from within an signal handler. If @aid is undefined, the agent calling wakeup will be woken up (if suspended).

timer.add

```
function (tmo:number, sig:string, arg:*,
repeat:boolean) → string
```

Adds and start a new timer that raises the signal sig after timeout. Returns a timer identifier.

timer.delete

```
function (sig:string)
```

Deletes a timer referenced by the identifier returned from timer.add.

A.7 Agent Control

Agents can be instantiated from an agent class template (previously loaded into the platform) by using the create operation with parameter initialisation. Agent class parameters must be passed immediately to agent body variables. They are not accessible during run-time!The agent class ac must be loaded previously as an agent class template and is provided by the platform. Alternatively, the agent class can be a sub-class of the current agent.

Furthermore, agents can be forked from the current agent process inheriting the entire data and control state including the current agent behaviour (activities, transitions, ..). Specific body variables of the forked agent can

be overridden by the attributes of the settings object passed on the fork call. Forking discards all current scheduling blocks, in contrast to migration!

A newly created agent is identified by a (node) unique identifier string (commonly 8 characters) that is returned by the create and fork operations.

At least privilege level 1 is required to use these operations.

A.7.1 Agent Creation Operations

create[1,2,3]

```
function (ac:string, [arg1,arg2,..], level?:number)
→ aid
```

```
function (ac:string, {arg1:*,arg2:*,..},
level?:number) → aid
```

Creates a new agent from agent class ac with the given set of arguments. The agent constructor function *ac* must be available on the platform. Agent class arguments are passed to agent class parameters during the creation or forking process. Arguments can either be passed in an array matching parameters in the order they are defined, or by using an argument object with arbitrary parameter order. Optionally the privilege level of the new agent can be specified, otherwise the new agent inherits the level of the creating agent. The highest level is limited to the level of the creating agent! The initial activity executed by the newly created agent is specified by the constructor function in the next attribute.

fork[1,2,3]

```
function (parameter:{var1:*, var2:*,..},
level?:number) → aid
```

Forks a copy of the current agent process inheriting the entire data and control state of the parent agent. The new child agent can reference its parent agent by the this.parent attribute or by using the myParent function. The child agent body variables var1, var2, .. passed by the parameters object are overridden on forking with the given values. Note that agent class parameters cannot be accessed after the creation of an aent. The next activity executed after the fork is either computed by the current transition entry or by a next variable override by the parameter object.

Example

```
id = create('explorer',{dir:DIR.NORTH,radius:1});
child = fork({x:10,y:20});
kill(child);
```

Among the creation and destruction of agents, the agent behaviour can be modified by agents by adding, deleting, or updating of transitions and activities (modification of the ATG). Only whole activities can only be changed and not code parts. There are two objects accessible by agents providing modification operations: `act` and `trans`. ATG transformations can be temporarily, e.g., used to create child agents with different or reduced behaviour.

A.7.2 Agent Behaviour Operations

act.add

```
function (act:string, code:function)
```

Adds a new activity @act with the given code to the current agent object.

act.delete

```
function (act:string)
```

Deletes activity @act from the current agent object.

act.update

```
function (act:string, code:function)
```

Updates code of activity @act of the current agent object.

trans.add

```
function (trans0:string, code:function|string)
```

Adds a new transition starting from activity @trans0 with the given code to the current agent object.

trans.delete

```
function (trans0:string)
```

Deletes a transition from activity @trans0 from the current agent object.

trans.update

```
function (trans0:string, code:function|string)
```

Updates code of transition starting from activity @trans0 of the current agent object.

Example

```
this.act = {
  a1: function () {..},
  a2: function () {
    act.delete(a1); trans.delete(a1);
    act.add('b1', function () {
      this.sensor=[]; ..});
    trans.update(a2, function () {
      return this.sensor.length>0?b1:a3 });
  },
  a3: ..
  ..
};
this.trans = {
  a1: a2,
  a2: a3,
  a3: ..
}
```

A.8 Process Control

The main control flow of and agent is related to the ATG and (conditional) transitions itself. An agent can call blocking statements within an activity. A blocked activity stops agent execution until an event occurs. But signal handlers can be still executed even the agent is in a blocked state. Among external suspend-wakeup control, the agent itself can suspend and resume its execution explicitly by the following operations. Blocking statements may only occur at the end of an activity (or at least there may be only one blocking statement in one activity).

sleep

```
function (millisec?:number)
```

Suspend agent execution (current activity) for a specific amount of time (milli seconds resolution) or until a wakeup operation (from within a signal handler) is executed.

wakeup

```
function (process?)
```

Wake up a sleeping (suspended) agent process.

A.9 Agent Mobility

Agent processes can migrate to another physical or logical node by transferring its current control and data snapshot via a message over a transport channel. The destination (specified by the transport channel) is selected by a direction DIR. If the moveto operation is executed at the end of an activity or the current scheduling block is empty after migration, the next activity is computed after migration on the new JAM node.

If a migration to a specific host or in a specific direction is not possible, a MOVE exception is thrown.

A.9.1 Types

```
enum DIR = {
  NORTH , SOUTH , WEST , EAST ,
  LEFT , RIGHT , UP , DOWN,
  ORIGIN ,
  NW , NE , SW , SE ,
  PATH (path:string),
  IP   (ip:string),
  NODE (node:string),
  CAP  (cap:string|capability)
} : dir
```

A.9.2 Operations

moveto[1,2]

```
function (to:dir)
```

Migrates current agent to a new node specified by the destination @to.

opposite

```
function (dir) → dir
```

Returns the opposite (back) direction (if any) of the given direction. E.g., opposite of NORTH is SOUTH. In the case of IP links and migration the *opposite* operation can return the IP address or the node name of the last node, i.e., opposite(DIR.IP()) and opposite(DIR.NODE()), respectively.

link

```
function (dir) → boolean|string|[]
```

Tests a link direction. Should be used prior to migration (migration with not available link direction causes an exception). In the case of multi-cast links (e.g., IP), a list of connected/reachable IPs (routes, using pattern IP('*')) or Nodes (using pattern IP('%')) is returned.

A.9.3 Example

```
// Activity in agent class template
move : function () {
  if (this.verbose>0) log('Move -> '+this.dir);
  if (!this.goback) this.backdir=opposite(this.dir);
  switch (this.dir) {
    case DIR.NORTH: this.delta.y--; break;
    case DIR.SOUTH: this.delta.y++; break;
    case DIR.WEST:  this.delta.x--; break;
    case DIR.EAST:  this.delta.x++; break;
  }
  if (this.dir!=DIR.ORIGIN && link(this.dir)) {
    this.hop++;
    moveto(this.dir);
  }
```

```
}
```

The possible migration directions depend on the network ports available on the agent's current node and the established links between nodes. IP (UDP/TCP/HTTP) links can be established between generic bidirectional (multicast) IP ports with (`DIR.IP("ip:ipport")`) or between uni-directional (uni-cast) ports, e.g., `DIR.NORTH("ip:ipport")`), commonly connected to a South port on the remote endpoint given by `DIR.SOUTH("ip:ipport")`), respectively . Generic IP ports can spawn arbitrary mesh grids. Alternatively, a destination node can be specified, i.e., `DIR.NODE(nodeid)`.

After an agent migration, the agent can retrieve its backpropagation direction, i.e., last node identifier or IP address by using the `opposite(DIR.NODE())` and `opposite(DIR.IP())` operations, respectively.

```
function mi(dest){
  this.src=null;
  this.dest=dest;
  this.act={
    init:function ()     {
     log('Starting on '+myNode())},
    goto: function ()    {
     log('Going to '+DIR.print(this.dest));
     if (link(this.dest)) moveto(this.dest);
     else log('No route')},
    goback: function () {
     this.src=opposite(DIR.NODE());
     log('Going back to '+DIR.print(this.src));
     moveto(this.src)},
    end: function ()     {
     log('End'); kill() }
  }
  this.trans={
    init:goto, goto:goback, goback:end
  }
  this.next=init
}
```

Example. Agent forward and backward migration between two nodes

Agent Input-Ouput System (AIOS)   Agent Mobility

A.10 Security

Changing of agent privilege levels and roles requires secured capabilities. Furthermore, agents can use capability protection to ensure authentication and authorisation of operations.

negotiate

```
function (resource:string, value:*, capability?) →
boolean
```

Negotiate an agent constraint parameter. Level 0 and 1 agents require a valid access capability with sufficient rights (0x80). The LEVEL resource is the agent privilege level. Supported resources are:

```
typeof
@resource='CPU'|'SCHED'|'MEM'|'TS'|'AGENT'|'LEVEL'
```

privilege

```
function () → number={0,1,2,3}
```

Returns the current privilege level of the agent

A.10.1 Capability

```
type port = string[6]
type privat = {
    prv_obj : number[0..65535],
    prv_rights : number[0..255],
    prv_rand : port
}
type capability = {
    cap_port: port,
    cap_prv: privat
}
```

A.10.2 Operations

The following capability and security functions are available.

Port

```
function (port_vals: numner []) → port
```

Creates a port (if *port_vals* is undefined a null port is returned).

Port.toString

```
function (port) → string
```

Returns a string representation of a port (XX:XX:XX:XX:XX)

Port.ofString

```
function (string) → port
```

Returns a port from a string representation (XX:XX:XX:XX:XX)

Port.unique

```
function () → port
```

Returns a fresh unique port from a random generator.

Private

```
function (obj:number, rights:number, rand:port) →
privat
```

Creates a private object (if *obj* is undefined a null private object is returned).

Private.toString

```
function (privat) → string
```

Returns a string representation of a private object (obj(rights)[XX:XX:XX:XX:XX])

Private.ofString

```
function (string) → privat
```

Returns a private object from a string representation (obj(rights)[XX:XX:XX:XX:XX])

Capability

```
function (port, privat) → capability
```

Creates a capability object (if *port* is undefined a null capability object is returned).

Capability.toString

```
function (capability) → string
```

Returns a string representation of a capability object (`[XX:XX:XX:XX:XX:XX]obj(rights)[XX:XX:XX:XX:XX]`)

Capability.ofString

```
function (string) → capability
```

Returns a capability object from a string representation (`[XX:XX:XX:XX:XX:XX]obj(rights)[XX:XX:XX:XX:XX]`)

A.11 Connectivity

connectTo[3]

```
function connectTo(dir:dir, @options)
```

Connects this node to another node using a virtual or physical channel link. Common ports are non-directed multi-cast IP ports. E.g., for connecting a node IP port to another IP port of a remote agent platform, the direction argument is `DIR.IP("<ipaddr>:<ipport>")` or by using the remote node name `DIR.NODE(<nodename>)`. Directional ports (supporting uni-cast P2P links only) like `DIR.NORTH` can be connected to another directional port by using the geometric opposite direction (in this example using `DIR.SOUTH` as destination). A different situation occurs if a directional port is established by IP communication (with an IP address and unique IP port). In this case the source port has to be specified (!) with the destination IP as an argument, e.g., `DIR.NORTH("<ipaddr>:<ipport>")`.

A.12 Scheduling

There are *AgentJS* operations that can block the agent processing, i.e., suspend the agent process and synchronising with events. But the JavaScript programming model does not support code blocking. For this reason, agent processing can only be suspended in transitions between activity (i.e., the activity is suspended, not the statement). Blocking *AgentJS/AIOS* statements (e.g., `sleep`, `inp`, ..) have to be placed at the end of an activity that is the only scheduling point. And there may be only one blocking statement in an activity. To support scheduling of a sequence of blocking statements, a scheduling block can be defined within an agent activity (but not within a transition that may not block).

B

```
function(block:function [])
```

Defines a scheduling block that is executed after the current activity defining the block has terminated. Each element of the function array is treated as an anonymous (sub-)activity and may contain a blocking statement.

I

```
function (object, next:function, block:function [],
finalize:function)
```

Iterates over object or array and applies the function block to each element.

L

```
function (init:function, cond:function,
next:function, block:function ]})
```

Loop block iteration with initialisation, conditional, and next computation function.

A.13 SQL

Level 3 (stationary) agents can access or create SQLite data bases. Requires either a native sqlite3 plug-in (embedded already in *jx+* and *pl3*, *node.js* requires loading of an external native module), or a pure

JavaScript implementation of the sqlite3 data base (default in *JAM*, relies on *emscripten* C2JS cross compilation).

A.13.1 Operations

db.Database[3]

```
function (filepath:string, options?:{mode:"r" |
"r+" | "w+"}) → sqldb
```

Creates a new data base or opens an existing from a file. A volatile data base can be created in memory by specifying a :memory: file path.

sqldb.createMatrix

```
function (matname:string, header:string | number |
boolean [], callback?:function) → boolean
```

Creates a new numeric matrix in the data base. The header argument provides the type interface for all rows.

sqldb.createTable

```
function (tblname:string, header:{},
callback?:function) → boolean
```

Creates a new data table in the data base. The header object specifies the column names.

sqldb.init

```
function ()
```

Initialize the SQL data base and start server.

sqldb.insertMatrix

```
function (mat:string, row:[], callback?:function)
→ boolean
```

Insert a new row in an already created matrix

sqldb.insertTable

```
function (tbl:string, row:[]|{},
callback?:function) → boolean
```

Insert a new row in an already created table

sqldb.readMatrix

```
function (mat:string, callback?:function) ->
[][]|none
```

Read entire matrix

sqldb.readTable

```
method (tbl:string, callback?:function) →
{}[]|none
```

Read entire table

A.14 Meta Data

```
Revision: 26/06/2019
Author: Dr. Stefan Bosse
```