

SCSCP

Symbolic Computation Software Composability Protocol

Version 2.4.2

7 July 2024

Olexandr Konovalov
Steve Linton

Olexandr Konovalov Email: [obk1 at st-andrews dot ac dot uk](mailto:obk1@st-andrews.ac.uk)

Homepage: <https://alex-konovalov.github.io/>

Address: School of Computer Science

University of St Andrews

Jack Cole Building, North Haugh,

St Andrews, Fife, KY16 9SX, Scotland

Steve Linton Email: [sal at cs dot st-andrews dot ac dot uk](mailto:sal@cs.st-andrews.ac.uk)

Homepage: <http://www.cs.st-andrews.ac.uk/~sal/>

Address: School of Computer Science

University of St Andrews

Jack Cole Building, North Haugh,

St Andrews, Fife, KY16 9SX, Scotland

Abstract

The GAP package SCSCP implements the Symbolic Computation Software Composability protocol (<https://www.openmath.org/standard/scscp/>) for the computational algebra system GAP.

Copyright

© 2007–2024 by Olexandr Kononov and Steve Linton

SCSCP is free software; you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation; either version 2 of the License, or (at your option) any later version. For details, see the FSF’s own site <https://www.gnu.org/licenses/gpl.html>.

If you obtained SCSCP, we would be grateful for a short notification sent to one of the authors.

If you publish a result which was partially obtained with the usage of SCSCP, please cite it in the following form:

O. Kononov and S. Linton. *SCSCP --- Symbolic Computation Software Composability Protocol, Version 2.4.2*; 2024 (<https://gap-packages.github.io/scscp/>).

Acknowledgements

The development of the SCSCP package has been supported by:

- EU FP6 Programme project 026133 “SCIENCE – Symbolic Computation Infrastructure for Europe”.
- OpenDreamKit Horizon 2020 European Research Infrastructures project #676541 (see <https://opendreamkit.org/>).

Colophon

Versions history:

- Version 0.1 – first half of 2007;
- Version 0.2 – December 2007;
- Version 0.3 – May 2008;
- Version 0.4 – August 2008;
- Version 1.0 – March 2009;
- Version 1.1 – May 2009;
- Version 1.2 – March 2010.

- Version 2.0 – October 2011.
- Version 2.1 – March 2012.
- Version 2.2 – February 2017.
- Version 2.3 – May 2019.

Contents

| | | |
|----------|---|-----------|
| 1 | Preface | 6 |
| 2 | Installation | 8 |
| 2.1 | Installation and system requirements | 8 |
| 2.2 | Configuration files | 8 |
| 3 | Using streams | 10 |
| 3.1 | Input-output TCP streams | 10 |
| 3.2 | Example of client-server communication via input-output TCP streams | 11 |
| 4 | Message exchange by SCSCP | 13 |
| 4.1 | Communication with the SCSCP server | 13 |
| 4.2 | Communication with the SCSCP client | 16 |
| 4.3 | Example: SCSCP session | 17 |
| 5 | Running SCSCP server | 18 |
| 5.1 | Installation of SCSCP procedures | 18 |
| 5.2 | Starting SCSCP server | 20 |
| 5.3 | Procedures to get information about the SCSCP server | 21 |
| 6 | Client's functionality | 25 |
| 6.1 | SCSCP connections | 25 |
| 6.2 | Processes | 26 |
| 6.3 | All-in-one tool: sending request and getting result | 28 |
| 6.4 | Switching between Binary and XML OpenMath Encodings | 29 |
| 6.5 | Remote objects | 33 |
| 7 | Examples of SCSCP usage | 37 |
| 7.1 | Providing services with the SCSCP package | 37 |
| 7.2 | Identifying groups of order 512 | 37 |
| 8 | Parallel computing with SCSCP | 40 |
| 8.1 | Managing multiple requests | 40 |
| 8.2 | MasterWorker skeleton | 42 |
| 8.3 | Example: parallelising Karatsuba multiplication for polynomials | 45 |

| | | |
|----------|----------------------------------|-----------|
| | <i>SCSCP</i> | 5 |
| 9 | Service functions | 48 |
| 9.1 | Pinging SCSCP servers | 48 |
| 9.2 | Info classes for SCSCP | 49 |
| 9.3 | Other SCSCP Utilities | 52 |
| | References | 55 |
| | Index | 56 |

Chapter 1

Preface

The GAP package SCSCP implements the Symbolic Computation Software Composability protocol [FHK⁺b]. This protocol specifies an OpenMath-based remote procedure call framework, in which all messages (procedure calls and returns of results of successful computation or error messages) are encoded in OpenMath using content dictionaries `scscp1` and `scscp2` ([FHK⁺a], [FHK⁺c]). Using the SCSCP package, GAP can communicate locally or remotely with any other OpenMath-enabled SCSCP-compliant application which may be not only another computer algebra system but also another instance of the GAP system or even, for example, an external Java or C/C++ application via libraries <http://java.symcomp.org/> or <http://www.imcce.fr/Equipes/ASD/trip/scscp/> providing an SCSCP API. Such communication will go into seamless manner for the GAP user, since all conversions from GAP to OpenMath and vice versa will be performed in the background. See the SCSCP protocol page <https://www.openmath.org/standard/scscp/> for the details about computer algebra systems and other software supporting SCSCP

The SCSCP package for GAP has two main components:

- SCSCP server;
- SCSCP client.

There are several ways to start GAP SCSCP server:

- call `RunSCSCPserver` (5.2.1) from the GAP session specifying the server name and the port number from the GAP session;
- start GAP as `gap myserver.g`, where `myserver.g` is the server configuration file with the last command being the call of `RunSCSCPserver` (5.2.1) (an example of such configuration file is given in `scscp/example/myserver.g`);
- start GAP as a daemon using the script `gapd.sh` which is supplied in the root directory of the package (for the description of all available options see comments in `gapd.sh`).

During startup the server installs all procedures that it will provide and loads their lookup mechanisms, and then begins to listen to the specified port. The recommended port number is 26133 which has been assigned to SCSCP by the Internet Assigned Numbers Authority (IANA) in November 2007, see <http://www.iana.org/assignments/port-numbers>.

When the server accepts a connection from client, it starts the "accept-evaluate-return" loop:

- accepts the "procedure_call"; message;

- performs lookup of the appropriate GAP function;
- evaluates the result (or produces a side-effect);
- returns the result in the "procedure_completed" message or returns an error in the "procedure_terminated" message.

The server works in a "multi-user" mode. When one client is connected, the server is busy for other clients. As soon as the computation is finished and the client is disconnected, the server is waiting for the next connection, and normally it never stops until it will be terminated by the service provider. The server maintain a queue of five incoming connections (this parameter can be easily modified), and on each iteration evaluates the next request from the queue.

The SCSCP client:

- establishes connection with the specified server at the specified port;
- sends the "procedure_call" message to the server;
- waits for the result of the computation or returns to pick it up later;
- fetches the response, extracting the result from the "procedure_completed" message or entering the break loop in the case of the "procedure_terminated" message.

On the top of this functionality we built a set of instructions for simple parallel computations framework using the SCSCP protocol, which allows to send several procedure calls in parallel and then collect all results or pick up the first available result, and implements the master-worker skeleton. These tools are presented in the Chapter 8.

The package also implements a new kind of GAP input-output streams, namely input-output TCP streams (see Chapter 3), based on the functionality for TCP/IP protocol usage provided by the GAP package IO. Such streams may constitute an independent interest for adapting streams-using GAP code to use streams across the network.

Finally, the manual describes how the communication by SCSCP goes between several instances of the GAP system, but the same behaviour is expected from any SCSCP-compliant application: the set of supported OpenMath symbols clearly will be different, but the rules of communication are precisely specified in the SCSCP specification [FHK⁺b]. See the SCSCP protocol page <https://www.openmath.org/standard/scscp/> for the information about SCSCP-compliant computer algebra systems and other tools developed in the project.

Chapter 2

Installation

2.1 Installation and system requirements

Both SCSCP client and server for GAP work in Linux, OS X and Windows.

To use the SCSCP package it is necessary to install recent versions of GAP4 packages IO [Neu], GAPDoc [LN] and OpenMath [CKNS].

The SCSCP package is distributed in standard formats (`tar.gz`, `tar.bz2`) and can be obtained from <https://gap-packages.github.io/scscp/> or from the GAP web site (the latter also offers `win.zip`-archives). To install SCSCP package, put its `tar.gz`-archive into the `pkg` subdirectory of your GAP4 installation and enter the command `tar -xzf scscp-X.X.X.tar.gz`, then the subdirectory `scscp` (containing subdirectories `doc`, `lib` etc.) will be created in the `pkg` subdirectory. Installation using other archive formats is performed in a similar way.

When there are no access rights to the root directory of the main GAP installation, it is also possible to install the package *outside the GAP main directory* by unpacking it inside a directory `MYGAPDIR/pkg`. Then to load the package GAP should be started with `-l " ;MYGAPDIR"` option.

2.2 Configuration files

There are four files in the package which may need to be modified to setup and customise the package. The first three files are related with the server's functionality:

- `scscp/config.g` specifies:
 - default `InfoLevel` for the `InfoSCSCP` (9.2.1) class;
 - default SCSCP server name and port to be used by `RunSCSCPserver` (5.2.1) if GAP is started with the `scscp/example/myserver.g` file;
 - whether the server accepts calls to procedures which are standard OpenMath symbols, or only procedures installed in the transient content dictionary (see `InstallSCSCPprocedure` (5.1.1));
 - service description to be returned to the client by `GetServiceDescription` (5.3.1).
- `scscp/gapd.sh` is the script to start the GAP SCSCP server as a daemon. To use it, adjust the local call of GAP and, if necessary, call options (for example, memory usage, startup from the workspace etc.) and the location of the root directory of the SCSCP package in section 1 of this script.

- `scscp/example/myserver.g` is an example of the server configuration file which loads all necessary packages, reads all needed code, installs all procedures which will be exposed to the client and finally starts the SCSCP server (see Chapter 5).

The fourth file is related with the client's functionality for parallel computations:

- The file `scscp/configpar.g` assigns the global variable `SCSCPservers` which specifies a list of hosts and ports to search for SCSCP services (which may be not only represented by GAP services, but also by another SCSCP-compliant systems). It will be used to run parallel computations with the SCSCP package (see Chapter 8).

See comments in these configuration files for further details and examples.

Chapter 3

Using streams

The package implements new kind of GAP input-output streams, called input-output TCP streams. Such streams are based on the functionality for the TCP/IP protocol usage provided by the GAP package IO, and may constitute an independent interest for GAP users.

Input-output TCP streams are intended to support all operations, implemented for streams in GAP. It is assumed that all existing code using streams should work with this kind of streams as well (please let us know, if you will notice that this is not the case!). We installed methods for input-output TCP streams to support the following operations: ViewObj (**Reference: ViewObj**), PrintObj (**Reference: PrintObj**), ReadByte (**Reference: ReadByte**), ReadLine (**Reference: ReadLine**), ReadAll (**Reference: ReadAll**), WriteByte (**Reference: WriteByte**), WriteLine (**Reference: WriteLine**), WriteAll (**Reference: WriteAll**), IsEndOfStream (**Reference: IsEndOfStream**), CloseStream (**Reference: CloseStream**), FileDescriptorOfStream (**Reference: FileDescriptorOfStream**), UNIXSelect (**Reference: UNIXSelect**).

3.1 Input-output TCP streams

3.1.1 IsInputOutputTCPStream

▷ IsInputOutputTCPStream (filter)

IsInputOutputTCPStream is a subcategory of IsInputOutputStream (**Reference: IsInputOutputStream**). Streams in the category IsInputOutputTCPStream are created with the help of the function InputOutputTCPStream (3.1.3) with one or two arguments dependently on whether they will be used in the client or server mode. Examples of their creation and usage will be given in subsequent sections.

3.1.2 IsInputOutputTCPStreamRep

▷ IsInputOutputTCPStreamRep (filter)

This is the representation used for streams in the category IsInputOutputTCPStream (3.1.1).

3.1.3 InputOutputTCPStream (for server)

- ▷ `InputOutputTCPStream(desc)` (function)
- ▷ `InputOutputTCPStream(host, port)` (function)

Returns: stream

The one-argument version must be called from the SCSCP server. Its argument *desc* must be a socket descriptor obtained using `IO_accept` (**IO: IO_accept**) function from the `IO` package (see the example below). It returns a stream in the category `IsInputOutputTCPStream` (3.1.1) which will use this socket to accept incoming connections. In most cases, the one-argument version is called automatically from `RunSCSCPserver` (5.2.1) rather than manually.

The version with two arguments, a string *host* and an integer *port*, must be called from the SCSCP client. It returns a stream in the category `IsInputOutputTCPStream` (3.1.1) which will be used by the client for communication with the SCSCP server running at hostname *host* on port *port*. In most cases, the two-argument version is called automatically from the higher level functions, for example, `EvaluateBySCSCP` (6.3.1).

3.2 Example of client-server communication via input-output TCP streams

The following example demonstrates the low-level interaction between client and server using input-output TCP stream, and shows how such streams are created in the function `RunSCSCPserver` (5.2.1). It uses some functions from the `IO` package (see the `IO` manual for their description). We will show step by step what is happens on server and client (of course, if you will try this example, the numbers denoting descriptors may be different).

First, we will start two **GAP** sessions, one for the server, another one for the client. Now we enter the following commands on the server's side:

Example

```
gap> sock := IO_socket( IO.PF_INET, IO.SOCK_STREAM, "tcp" );
3
gap> lookup := IO_gethostbyname( "localhost" );
rec( name := "localhost", aliases := [ ], addrtype := 2, length := 4,
    addr := [ "\177\000\000\>" ] )
gap> port:=26133;
26133
gap> res := IO_bind( sock, IO_make_sockaddr_in( lookup.addr[1], port ) );
true
gap> IO_listen( sock, 5 );
true
gap> socket_descriptor := IO_accept( sock, IO_MakeIPAddressPort("0.0.0.0",0) );
```

After the last command you will not see the **GAP** prompt because the server starts to wait for an incoming connection. Now we go to the client's side and create an input-output TCP stream to the server. Here it can be created in one step:

Example

```
gap> clientstream:=InputOutputTCPStream( "localhost", 26133 );
Creating a socket...
```

```
Connecting to a remote socket via TCP/IP...
```

Now we are trying to connect to the server, and as soon as the connection will be established, the stream will be created at the client side, and we will see the output and the new **GAP** prompt:

Example

```
< input/output TCP stream to localhost >
gap>
```

On the server you will get the socket descriptor and then you will be able to create a stream from it:

Example

```
4
gap> serverstream := InputOutputTCPStream( socket_descriptor );
< input/output TCP stream to socket >
```

Now we can write to this stream on the client side and then read from it on the server side and backwards. First, write on the client:

Example

```
gap> WriteLine( clientstream, "12345" );
true
```

Now read and write on the server:

Example

```
gap> ReadLine( serverstream );
"12345\n"
gap> WriteLine( serverstream, "54321" );
true
```

And finally we read on the client and close the stream:

Example

```
gap> ReadLine( clientstream );
"54321\n"
gap> CloseStream( clientstream );
```

and similarly close the stream on the server:

Example

```
gap> CloseStream( serverstream );
```

In this way one can organise remote communication between two copies of **GAP** in various ways. In subsequent chapters we explain how it is implemented using **SCSCP** to ensure compatibility not only with **GAP** but with any other **SCSCP**-compliant system.

Chapter 4

Message exchange by SCSCP

To ensure the message exchange as required by SCSCP specification, the SCSCP package extends the global record `OMsymRecord` from the `OpenMath` package with new entries to support `scscp1` and `scscp2` content dictionaries ([FHK⁺a], [FHK⁺c]), and also service-dependent transient private content dictionaries (see Chapter 5 for details about transient content dictionaries). It also overwrites some `OpenMath` functions by their extended (but backwards compatible) versions, and adds some new `OpenMath`-related functions to send and receive SCSCP messages, documented below.

Note that functions documented in this chapter belong to the middle-level interface, and the user may find it more convenient to use functions developed on top of them and explained in next chapters.

4.1 Communication with the SCSCP server

4.1.1 StartSCSCPsession

▷ `StartSCSCPsession(stream)` (function)

Returns: string

Initialises SCSCP session and negotiates with the server about the version of the protocol. Returns the string with the `service_id` (which may be used later as a part of the call identifier) or causes an error message if can not perform these tasks.

Example

```
gap> s := InputOutputTCPStream("localhost",26133);  
< input/output TCP stream to localhost:26133 >  
gap> StartSCSCPsession(s);  
"localhost:26133:5541"  
gap> CloseStream( s );
```

After the call to `StartSCSCPsession` the SCSCP server is ready to accept procedure calls.

4.1.2 OMPutProcedureCall

▷ `OMPutProcedureCall(stream, proc_name, objrec)` (function)

Returns: nothing

Takes a stream `stream`, the string `proc_name` and a record `objrec`, and writes to `stream` an `OpenMath` object `procedure_call` for the procedure `proc_name` with arguments given by the list

`objrec.object` and procedure call options (which should be encoded as OpenMath attributes) given in the list `objrec.attributes`.

This function accepts options `cd` and `debuglevel`.

`cd:="cdname"` may be used to specify the name of the content dictionary if the procedure is actually a standard OpenMath symbol. Note that the server may reject such a call if it accepts only calls of procedures from the transient content dictionary, see `InstallSCSCPprocedure` (5.1.1) for explanation). If the `cdname` is not specified, `scscp_transient_1` content dictionary will be assumed by default. The value of the `debuglevel` option is an integer. If it is non-zero, the `procedure_completed` message will carry on also some additional information about the call, for example, runtime and memory used.

Example

```
gap> t:=""; stream:=OutputTextString(t,true);;
gap> OMPutProcedureCall( stream, "WS_Factorial", rec( object:= [ 5 ],
>   attributes:=[ [ "call_id", "user007" ],
>                 ["option_runtime",1000],
>                 ["option_min_memory",1024],
>                 ["option_max_memory",2048],
>                 ["option_debuglevel",1],
>                 ["option_return_object"] ] ) );;
gap> Print(t);
<?scscp start ?>
<OMOBJ xmlns="http://www.openmath.org/OpenMath" version="2.0">
  <OMATTR>
    <OMATP>
      <OMS cd="scscp1" name="call_id"/>
      <OMSTR>user007</OMSTR>
      <OMS cd="scscp1" name="option_runtime"/>
      <OMI>1000</OMI>
      <OMS cd="scscp1" name="option_min_memory"/>
      <OMI>1024</OMI>
      <OMS cd="scscp1" name="option_max_memory"/>
      <OMI>2048</OMI>
      <OMS cd="scscp1" name="option_debuglevel"/>
      <OMI>1</OMI>
      <OMS cd="scscp1" name="option_return_object"/>
      <OMSTR></OMSTR>
    </OMATP>
    <OMA>
      <OMS cd="scscp1" name="procedure_call"/>
      <OMA>
        <OMS cd="scscp_transient_1" name="WS_Factorial"/>
        <OMI>5</OMI>
      </OMA>
    </OMA>
  </OMATTR>
</OMOBJ>
<?scscp end ?>
```

4.1.3 SCSCPwait

▷ SCSCPwait(*stream* [, *timeout*])

(function)

Returns: nothing

This function may be used by the SCSCP client to wait (using `IO_select` (**IO:** `IO_select`)) until the result of the procedure call will be available from *stream*. By default the timeout is one hour, to specify another value give it as the optional second argument in seconds. See the end of this chapter for the example.

4.1.4 OMGetObjectWithAttributes

▷ OMGetObjectWithAttributes(*stream*)

(function)

Returns: record with components object and attributes, or fail

This function is similar to the function `OMGetObject` from the `OpenMath` package, and the main difference is that it is able to understand `OpenMath` attribution pairs. It retrieves exactly one `OpenMath` object from the stream *stream*, and stores it in the object component of the returned record. If the `OpenMath` object has no attributes, the attributes component of the returned record will be an empty list, otherwise it will contain pairs [attribute_name, attribute_value], where attribute_name is a string, and attribute_value is a `GAP` object, whose type is determined by the kind of an attribute. Only attributes, defined by the SCSCP are allowed, otherwise an error message will be displayed.

If the procedure was not successful, the function returns `fail` instead of an error message like the function `OMGetObject` (**OpenMath:** `OMGetObject`) does. Returning `fail` is useful when `OMGetObjectWithAttributes` is used inside accept-evaluate-return loop.

As an example, the file `scscp/tst/omdemo.om` contains some `OpenMath` objects, including those from the SCSCP Specification [FHK⁺b]. We can retrieve them from this file, preliminary installing some SCSCP procedures using the function `InstallSCSCPprocedure` (5.1.1):

Example

```
gap> InstallSCSCPprocedure("WS_Factorial", Factorial );
gap> InstallSCSCPprocedure("GroupIdentificationService", IdGroup );
gap> InstallSCSCPprocedure("GroupByIdNumber", SmallGroup );
gap> InstallSCSCPprocedure( "Length", Length, 1, 1 );
gap> test:=Filename( Directory( Concatenation(
>     GAPInfo.PackagesInfo("scscp")[1].InstallationPath,"/tst/" ) ),
>     "omdemo.om" );;
gap> stream:=InputTextFile(test);;
gap> OMGetObjectWithAttributes(stream);
rec(
  attributes := [ [ "option_return_object", "" ], [ "call_id", "5rc6rtG62" ] ]
    , object := 6 )
gap> OMGetObjectWithAttributes(stream);
rec( attributes := [ ], object := 1 )
gap> OMGetObjectWithAttributes(stream);
rec( attributes := [ ], object := 120 )
gap> OMGetObjectWithAttributes(stream);
rec(
  attributes := [ [ "call_id", "alexk_9053" ], [ "option_runtime", 300000 ],
    [ "option_min_memory", 40964 ], [ "option_max_memory", 134217728 ],
    [ "option_debuglevel", 2 ], [ "option_return_object", "" ] ],
```

```

    object := [ 24, 12 ] )
gap> OMGetObjectWithAttributes(stream);
rec(
  attributes := [ [ "call_id", "alexk_9053" ], [ "option_return_cookie", "" ]
    ], object := <pc group of size 24 with 4 generators> )
gap> OMGetObjectWithAttributes(stream);
rec( attributes := [ [ "call_id", "alexk_9053" ], [ "info_runtime", 1234 ],
  [ "info_memory", 134217728 ] ], object := [ 24, 12 ] )
gap> CloseStream( stream );

```

4.2 Communication with the SCSCP client

4.2.1 OMPutProcedureCompleted

▷ OMPutProcedureCompleted(*stream*, *objrec*) (function)

Returns: true

Takes a stream *stream*, and a record *objrec*, and writes to *stream* an OpenMath object procedure_completed with the result being *objrec*.object and information messages (as OpenMath attributes) given in the list *objrec*.attributes.

Example

```

gap> t:=""; stream:=OutputTextString(t,true);;
gap> OMPutProcedureCompleted( stream,
>   rec(object:=120,
>   attributes:=[ [ "call_id", "user007" ] ] ) );
true
gap> Print(t);
<?scscp start ?>
<OMOBJ xmlns="http://www.openmath.org/OpenMath" version="2.0">
  <OMATTR>
    <OMATP>
      <OMS cd="scscp1" name="call_id"/>
      <OMSTR>user007</OMSTR>
    </OMATP>
    <OMA>
      <OMS cd="scscp1" name="procedure_completed"/>
      <OMI>120</OMI>
    </OMA>
  </OMATTR>
</OMOBJ>
<?scscp end ?>

```

4.2.2 OMPutProcedureTerminated

▷ OMPutProcedureTerminated(*stream*, *objrec*, *error_cd*, *error_type*) (function)

Returns: nothing

Takes a stream *stream*, and a record with an error message *objrec* (for example *rec*(attributes := [["call_id", "localhost:26133:87643:gcX33cCf"]], object :=

"localhost:26133 reports : Rational operations: <divisor> must not be zero") and writes to the *stream* an OpenMath object *procedure_terminated* containing an error determined by the symbol *error_type* from the content dictionary *error_cd* (for example, *error_memory*, *error_runtime* or *error_system_specific* from the *scscp1* content dictionary ([FHK⁺a])).

This is the internal function of the package which is used only in the code for the SCSCP server to return the error message to the client.

4.3 Example: SCSCP session

In the following example we start an SCSCP session and perform ten procedure calls in a loop before closing that session. Note that we demonstrate the usage of the session ID *sid* and the function *RandomString* from the *OpenMath* package to produce some unique call identifier. The call ID is a mandatory attribute for any procedure call, however, it is not necessarily random; for example, it may be just a string with the number of the procedure call.

Example

```
gap> stream:=InputOutputTCPStream( "localhost", 26133 );
< input/output TCP stream to localhost:26133 >
gap> sid := StartSCSCPsession( stream );
"localhost:26133:5541"
gap> res:=[];
[ ]
gap> for i in [1..10] do
>   OMPutProcedureCall( stream, "WS_Factorial",
>     rec( object := [ i ],
>       attributes := [ [ "call_id",
>         Concatenation( sid, ":", RandomString(8) ) ] ] ) );
>   SCSCPwait( stream );
>   res[i]:=OMGetObjectWithAttributes( stream ).object;
> od;
gap> CloseStream(stream);
gap> res;
[ 1, 2, 6, 24, 120, 720, 5040, 40320, 362880, 3628800 ]
```

Also note the usage of *SCSCPwait* (4.1.3) to wait until the result of the computation will be available from *stream*.

In this example we assumed that there is an SCSCP server running at localhost, port 26133. In the next chapter we will explain how to configure and run a GAP SCSCP server and how to interrogate it from a GAP client to learn about its functionality. After that, we will proceed with the SCSCP client functionality for the end-user.

Chapter 5

Running SCSCP server

5.1 Installation of SCSCP procedures

There may various ways to run SCSCP server, for example:

- allowing generic services like evaluation of arbitrary OpenMath code;
- offering highly specialized procedures like identification of groups of order 512;
- providing access to a database of mathematical objects.

Each of these use cases requires certain control over the level of functionality exposed to the client. To achieve this, before starting SCSCP service its provider must call the function `InstallSCSCPprocedure` (5.1.1) to make required procedures “visible” for the client.

Additionally, the service can be made made accessible only for clients running on the same computer, or accessible only through a particular network interface, or generally accessible. This customization is made at the stage of starting the SCSCP server with the function `RunSCSCPserver` (5.2.1).

5.1.1 InstallSCSCPprocedure

▷ `InstallSCSCPprocedure(procname, profunc[, description][, narg1[, narg2][, signature]])` (function)

Returns: nothing

For a string *procname* and a function *profunc*, `InstallSCSCPprocedure` makes the *profunc* available as SCSCP procedure under the name *procname*, adding it to the transient OpenMath content dictionary `scscp_transient_1` that will exist during the service lifetime.

The second argument *profunc* may be either a standard or user-defined GAP function (procedure, operation, etc.).

The rest of arguments are optional and may be used in a number of combinations:

- *description* is a string with the description of the procedure. It may be used by the help system. If it is omitted, the procedure will be reported as undocumented.
- *narg1* is a non-negative integer, specifying the minimal number of arguments, and *narg2* is a non-negative integer or infinity, specifying the maximal number of arguments. If *narg2* is omitted then the maximal number of arguments will be set to *narg1*. If both *narg1* and *narg2*

are omitted then the minimal number of arguments will be set to zero and their maximal number will be set to infinity.

- *signature* is the signature record of the procedure. If the *signature* is given, then the number of arguments must be explicitly specified (by *narg1* with or without *narg2*) at least to zero and infinity respectively (to ensure proper matching of arguments). Note that it is completely acceptable for a symbol from a transient content dictionary to overstate the set of symbols which may occur in its children using the `scscp2.symbol_set_all` symbol, and to use standard **OpenMath** errors to reject requests later at the stage of their evaluation. For example, using such approach, we will define the procedure `WS_Factorial` accepting not only immediate <OMI> objects but anything which could be evaluated to an integer.

. The signature must be either a list of records, where *i*-th record corresponds to the *i*-th argument, or a record itself meaning that it specifies the signature for all arguments. In the latter case the record may be `rec()` corresponding to the `scscp2.symbol_set_all` symbol (this will be assumed by default if the signature will be omitted).

If more detailed description of allowed arguments is needed, the signature record (one for all arguments or a specific one) may have components `CDgroups`, `CDs` and `Symbols`. The first two are lists of names of content dictionary groups and content dictionaries, and the third is a record whose components are names of content dictionaries, containing lists of names of allowed symbols from these dictionaries, for example:

Example

```
signature := rec( CDgroups := [ "scscp" ],
                  CDs := [ "arith1", "linalg1" ],
                  Symbols := rec( polyd1 := [ "DMP", "term", "SDMP" ],
                                polyu := [ "poly_u_rep", "term" ] ) );
```

In the following example we define the function `WS_Factorial` that takes an integers and returns its factorial, using only mandatory arguments of `InstallSCSCPprocedure`:

Example

```
gap> InstallSCSCPprocedure( "WS_Factorial", Factorial );
InstallSCSCPprocedure : procedure WS_Factorial installed.
```

In the following example we install the procedure that will accept a list of permutations and return the number in the **GAP** Small Groups library of the group they generate (for the sake of simplicity we omit tests of validity of arguments, availability of `IdGroup` for groups of given order etc.)

Example

```
gap> IdGroupByGenerators:=function( permlist )
> return IdGroup( Group( permlist ) );
> end;
function( permlist ) ... end
gap> InstallSCSCPprocedure( "GroupIdentificationService", IdGroupByGenerators );
InstallSCSCPprocedure : procedure GroupIdentificationService installed.
```

After installation, the procedure may be reinstalled, if necessary:

Example

```
gap> InstallSCSCPprocedure( "WS_Factorial", Factorial );
WS_Factorial is already installed. Do you want to reinstall it [y/n]? y
InstallSCSCPprocedure : procedure WS_Factorial reinstalled.
```

Finally, some examples of various combinations of optional arguments:

Example

```
InstallSCSCPprocedure( "WS_Phi", Phi,
                      "Euler's totient function, see ?Phi in GAP", 1, 1 );
InstallSCSCPprocedure( "GroupIdentificationService",
                      IdGroupByGenerators, 1, infinity, rec() );
InstallSCSCPprocedure( "IdGroup512ByCode", IdGroup512ByCode, 1 );
InstallSCSCPprocedure( "WS_IdGroup", IdGroup, "See ?IdGroup in GAP" );
```

Note that it is quite acceptable to overstate the signature of the procedure and use only mandatory arguments in a call to `InstallSCSCPprocedure`, which will be installed then as a procedure that can accept arbitrary number of arguments encoded without any restrictions on `OpenMath` symbols used, because anyway the `GAP` system will return an error in case of the wrong number or type of arguments, though it might be a good practice to give a way to the client to get more precise procedure description a priori, that is before sending request. See 5.3 about utilities for obtaining such information about the `SCSCP` service.

Some more examples of installation of `SCSCP` procedures are given in the file `scscp/example/myserver.g`.

5.1.2 OMSymRecord

▷ `OMSymRecord`

(global variable)

This is the global record from the `OpenMath` package used for the conversion from `OpenMath` to `GAP`. It is extended in the `SCSCP` package by adding support for symbols from `scscp1` and `scscp2` content dictionaries ([[FHK⁺a](#)], [[FHK⁺c](#)]). Additionally, `InstallSCSCPprocedure` (5.1.1) adds to this record a component corresponding to the appropriate transient content dictionary (by default, `scscp_transient_1`) defining mappings between `OpenMath` symbols from this content dictionary and installed `SCSCP` procedures.

5.2 Starting SCSCP server

5.2.1 RunSCSCPserver

▷ `RunSCSCPserver(servertype, port)`

(function)

Returns: nothing

Will start the `SCSCP` server at port given by the integer `port`. The first parameter `servertype` is either `true`, `false` or a string containing the server hostname:

- when `servertype` is `true`, the server will be started in a “universal” mode and will accept all incoming connections;
- when `servertype` is `false`, the server will be started at `localhost` and will not accept any incoming connections from outside;
- when `servertype` is a string, for example, `"scscp.gap-system.org"`, the server will be accessible only by specified server name (this may be useful to manage accessibility if, for example, the hardware has several network interfaces).

Example

```
gap> RunSCSCPserver( "localhost", 26133 );
Ready to accept TCP/IP connections at localhost:26133 ...
Waiting for new client connection at localhost:26133 ...
```

Actually, there is more than one way to run GAP SCSCP server:

- from the GAP session as shown in the example above;
- starting GAP as `gap myserver.g`, where `myserver.g` is the server configuration file with the last command being the call `RunSCSCPserver` (5.2.1), which may take its arguments from the configuration file `scscp/config.g` (an example of such configuration file is given in `scscp/example/myserver.g`);
- start GAP as a daemon using the script `gapd.sh` which is supplied in the root directory of the package (for the description of all available options see comments in `gapd.sh`) and may overwrite parameters from `scscp/config.g`.

See Section 2.2 about configuring files `config.g` and `gapd.sh`.

5.3 Procedures to get information about the SCSCP server

5.3.1 GetServiceDescription

▷ `GetServiceDescription(server, port)` (function)

Returns: record

Returns the record with three components containing strings with the name, version and description of the service as specified by the service provider in the `scscp/config.g` (for details about configuration files, see 2.2).

Example

```
gap> GetServiceDescription( "localhost", 26133 );
rec(
  description := "Started with the configuration file scscp/example/myserver.g\
on Thu 16 Feb 2017 16:03:56 GMT", service_name := "GAP SCSCP service",
  version := "GAP 4.8.6 + SCSCP 2.2.1" )
```

5.3.2 GetAllowedHeads

▷ `GetAllowedHeads(server, port)`

(function)

Returns: record

Returns the record with components corresponding to content dictionaries. The name of each component is the name of the content dictionary, and its value is either a boolean or a list of strings. In case its value is a list, it contains names of symbols from the corresponding content dictionary which are allowed to appear as a “head” symbol (i.e. the first child of the outermost <OMA>) in an SCSCP procedure call to the SCSCP server running at `server:port`. If its value is `true`, it means the server allows all symbols from the corresponding content dictionary.

Note that it is acceptable (although not quite desirable) for a server to “overstate” the set of symbols it accepts and use standard OpenMath errors to reject requests later.

Example

```
gap> GetAllowedHeads("localhost",26133);
rec( scscp_transient_1 := [ "AClosestVectorCombinationsMatFFVecFFE",
  "Determinant", "GroupIdentificationService",
  "IO_UnpickleStringAndPickleItBack", "IdGroup512ByCode", "Identity",
  "IsPrimeInt", "Length", "MathieuGroup", "MatrixGroup",
  "NormalizedUnitCFcommutator", "NormalizedUnitCFpower",
  "NrConjugacyClasses", "NrSmallGroups", "NumberCFGGroups",
  "NumberCFSolvableGroups", "PointImages", "QuillenSeriesByIdGroup",
  "ResetMinimumDistanceService", "SCSCPStartTracing", "SCSCPStopTracing",
  "Size", "SylowSubgroup", "WS_AlternatingGroup", "WS_AutomorphismGroup",
  "WS_ConwayPolynomial", "WS_Factorial", "WS_FactorsCFRAC",
  "WS_FactorsECM", "WS_FactorsMPQS", "WS_FactorsPminus1",
  "WS_FactorsPplus1", "WS_FactorsTD", "WS_IdGroup", "WS_LatticeSubgroups",
  "WS_Mult", "WS_MultMatrix", "WS_Phi", "WS_PrimitiveGroup",
  "WS_SmallGroup", "WS_SymmetricGroup", "WS_TransitiveGroup", "addition"
] )
```

5.3.3 IsAllowedHead

▷ `IsAllowedHead(cd, symbol, server, port)`

(function)

Returns: `true` or `false`

Checks whether the OpenMath symbol `cd.symbol`, which may be a symbol from a standard or transient OpenMath content dictionary, is allowed to appear as “head” symbol (i.e. the first child of the outermost <OMA>) in an SCSCP procedure call to the SCSCP server running at `server:port`. This enables the client to check whether a particular symbol is allowed without requesting the full list of symbols.

Also, it is acceptable (although not necessarily desirable) for a server to “overstate” the set of symbols it accepts and use standard OpenMath errors to reject requests later.

Example

```
gap> IsAllowedHead( "permgp1", "group", "localhost", 26133 );
true
gap> IsAllowedHead( "setname1", "Q", "localhost", 26133 );
true
gap> IsAllowedHead( "setname1", "R", "localhost", 26133 );
```

```
false
```

5.3.4 GetTransientCD

▷ `GetTransientCD(transient_cd, server, port)` (function)

Returns: record

Returns a record with the transient content dictionary *transient_cd* from the SCSCP server running at *server:port*. Names of components of this record correspond to symbols from the meta content dictionary.

By default, the name of the transient content dictionary for the GAP SCSCP server is *scscp_transient_1*. Other systems may use transient content dictionaries with another names, which, however, must always begin with *scscp_transient_* and may be guessed from the output of `GetAllowedHeads` (5.3.2).

Example

```
gap> GetTransientCD( "scscp_transient_1", "localhost", 26133 );
rec( CDDate := "2017-02-08",
     CDDefinitions :=
       [ rec( Description := "Size is currently undocumented.", Name := "Size" ),
         rec( Description := "Length is currently undocumented.",
             Name := "Length" ),
         rec( Description := "NrConjugacyClasses is currently undocumented.",
             Name := "NrConjugacyClasses" ),
         ...
         rec( Description := "MatrixGroup is currently undocumented.",
             Name := "MatrixGroup" ) ], CDName := "scscp_transient_1",
     CDReviewDate := "2017-02-08", CDRevision := "0", CDStatus := "private",
     CDVersion := "0",
     Description := "This is a transient CD for the GAP SCSCP service" )
```

5.3.5 GetSignature

▷ `GetSignature(transientcd, symbol, server, port)` (function)

Returns: record

Returns a record with the signature of the OpenMath symbol *transientcd.symbol* from a transient OpenMath content dictionary. This record contains components corresponding to the OpenMath symbol whose signature is described, the minimal and maximal number of its children (that is, of its arguments), and symbols which may be used in the OpenMath encoding of its children. Note that it is acceptable for a symbol from a transient content dictionary to overstate the set of symbols which may occur in its children using the *scscp2.symbol_set_all* symbol, and use standard OpenMath errors to reject requests later, like in the example below: using such approach, the procedure *WS_Factorial* is defined to accept not only immediate <OMI> objects but anything which could be evaluated to an integer.

Example

```
gap> GetSignature("scscp_transient_1", "WS_Factorial", "localhost", 26133);
rec( maxarg := 1, minarg := 1,
```

```
symbol := rec( cd := "scscp_transient_1", name := "WS_Factorial" ),  
symbolargs := rec( cd := "scscp2", name := "symbol_set_all" ) )
```


Chapter 6

Client's functionality

Sending and getting requests to the SCSCP server(s), the client operates with processes. Process is an abstraction which in other words may be also called a remote task. It encapsulates an input/output TCP stream (see `IsInputOutputTCPStream` (3.1.1)) from the client to the server and the process ID of the CAS running as a server (deduced from the connection initiation message; may be unassigned, if the server CAS did not communicate it).

There are two ways to create processes. One of them is to specify the hostname and port where the SCSCP server is running; in this case a new input/output TCP stream will be created. Another way is first to establish the connection with the SCSCP server using `NewSCSCPconnection` (6.1.2) and then keep it alive across multiple remote procedure calls, thus saving time on the DNS lookup and connection initiation. This may give a good speedup in computations with an intensive message exchange. Note that as long as such connection is open, other SCSCP clients will not be able to get through, so if several clients are interchanging with the SCSCP server at the same time, they should not block each other with long-lasting connections.

6.1 SCSCP connections

6.1.1 IsSCSCPconnection

▷ `IsSCSCPconnection` (filter)

This is the category of SCSCP connections. Objects in this category are created using the function `NewSCSCPconnection` (6.1.2).

6.1.2 NewSCSCPconnection

▷ `NewSCSCPconnection(hostname, port)` (function)

For a string *hostname* and an integer *port*, creates an object in the category `IsSCSCPconnection` (6.1.1). This object will encapsulate two objects: `tcpstream`, which is the input/output TCP stream to *hostname:port*, and `session_id`, which is the result of calling `StartSCSCPsession` (4.1.1) on `tcpstream`. The connection will be kept alive across multiple remote procedure calls until it will be closed with `CloseSCSCPconnection` (6.1.3).

Example

```
gap> SetInfoLevel( InfoSCSCP, 2 );
gap> s:=NewSCSCPconnection("localhost",26133);
#I Creating a socket ...
#I Connecting to a remote socket via TCP/IP ...
#I Got connection initiation message
#I <?scscp service_name="GAP" service_version="4.dev" service_id="localhost:2\
6133:52918" scscp_versions="1.0 1.1 1.2 1.3" ?>
#I Requesting version 1.3 from the server ...
#I Server confirmed version 1.3 to the client ...
< connection to localhost:26133 session_id=localhost:26133:52918 >
gap> CloseSCSCPconnection(s);
```

6.1.3 CloseSCSCPconnection

▷ CloseSCSCPconnection(*s*)

(function)

Returns: nothing

Closes SCSCP connection *s*, which must be an object in the category IsSCSCPconnection (6.1.1). Internally, it just calls CloseStream (**Reference:** CloseStream) on the underlying input/output TCP stream of *s*.

Example

```
gap> SetInfoLevel( InfoSCSCP, 0 );
gap> s:=NewSCSCPconnection("localhost",26133);
< connection to localhost:26133 session_id=localhost:26133:52918 >
gap> CloseSCSCPconnection(s);
```

6.2 Processes

6.2.1 IsProcess

▷ IsProcess

(filter)

This is the category of processes. Processes in this category are created using the function NewProcess (6.2.2).

6.2.2 NewProcess

▷ NewProcess(*command*, *listargs*, *server*, *port*)

(function)

▷ NewProcess(*command*, *listargs*, *connection*)

(function)

Returns: object in the category IsProcess

In the first form, *command* and *server* are strings, *listargs* is a list of GAP objects and *port* is an integer.

In the second form, an SCSCP connection in the category NewSCSCPconnection (6.1.2) is used instead of *server* and *port*.

Calls the SCSCP procedure with the name *command* and the list of arguments *listargs* at the server and port given by *server* and *port* or encapsulated in the *connection*. Returns an object in the category *IsProcess* for the subsequent waiting the result from its underlying stream.

It accepts the following options:

- `output:="object"` is used to specify that the server must return the actual object evaluated as a result of the procedure call. This is the default action requested by the client if the output option is omitted.
- `output:="cookie"` is used to specify that the result of the procedure call should be stored on the server, and the server should return a remote object (see 6.5) pointing to that result (that is, a cookie);
- `output:="nothing"` is used to specify that the server is supposed to reply with a `procedure_completed` message carrying no object just to signal that the call was completed successfully (for the compatibility, this will be evaluated to a "procedure completed" string on the client's side);
- `cd:="cdname"` is used to specify that the *OpenMath* symbol corresponding to the first argument *command* should be looked up in the particular content dictionary *cdname*. Otherwise, it will be looked for in the default content dictionary (`scscp_transient_1` for the GAP SCSCP server);
- `debuglevel:=N` is used to obtain additional information attributes together with the result. The GAP SCSCP server does the following: if `N=1`, it will report about the CPU time in milliseconds required to compute the result; if `N=2` it will additionally report about the amount of memory used by GAP in bytes will be returned (using the output of `MemoryUsageByGAPinKbytes` (9.3.4) converted to bytes); if `N=3` it will additionally report the amount of memory in bytes used by the resulting object and its subobjects (using the output of `MemoryUsage` (**Reference: MemoryUsage**)).

See `CompleteProcess` (6.2.3) and `EvaluateBySCSCP` (6.3.1) for examples.

6.2.3 CompleteProcess

▷ `CompleteProcess(process)`

(function)

Returns: record with components `object` and `attributes`

The function waits, if necessary, until the underlying stream of the process will contain some data, then reads the appropriate *OpenMath* object from this stream and closes it.

It has the option `output` which may have two values:

- `output:="cookie"` has the same meaning as for the `NewProcess` (6.2.2)
- `output:="tree"` is used to specify that the result obtained from the server should be returned as an XML parsed tree without its evaluation.

In the following example we demonstrate combination of the two previous functions to send request and get result, calling the procedure `WS_Factorial`, installed in the previous chapter:

Example

```
gap> s := NewProcess( "WS_Factorial", [10], "localhost", 26133 );
< process at localhost:26133 pid=52918 >
gap> x := CompleteProcess(s);
rec( attributes := [ [ "call_id", "localhost:26133:52918:TPNiMjCT" ] ],
      object := 3628800 )
```

See more examples in the description of the function `EvaluateBySCSCP` (6.3.1), which combines the two previous functions by sending request and getting result in one call.

6.2.4 TerminateProcess

▷ `TerminateProcess(process)`

(function)

The function is supposed to send an “out-of-band” interrupt signal to the server. Current implementation works only when the server is running as “localhost” by sending a SIGINT to the server using its PID contained in the *process*. It will do nothing if the server is running remotely, as the SCSCP specification allows the server to ignore interrupt messages. Remote interrupts will be introduced in one of the next versions of the package.

6.3 All-in-one tool: sending request and getting result

6.3.1 EvaluateBySCSCP

▷ `EvaluateBySCSCP(command, listargs, server, port)`

(function)

▷ `EvaluateBySCSCP(command, listargs, connection)`

(function)

Returns: record with components *object* and *attributes*

In the first form, *command* and *server* are strings, *listargs* is a list of GAP objects and *port* is an integer.

In the second form, an SCSCP connection in the category `NewSCSCPconnection` (6.1.2) is used instead of *server* and *port*.

Calls the SCSCP procedure with the name *command* and the list of arguments *listargs* at the server and port given by *server* and *port* or encapsulated in the *connection*.

Since `EvaluateBySCSCP` combines `NewProcess` (6.2.2) and `CompleteProcess` (6.2.3), it accepts all options which may be used by that functions (*output*, *cd* and *debuglevel*) with the same meanings.

Example

```
gap> EvaluateBySCSCP( "WS_Factorial", [10], "localhost", 26133 );
rec( attributes := [ [ "call_id", "localhost:26133:2442:6hMEN40d" ] ],
      object := 3628800 )
gap> SetInfoLevel(InfoSCSCP,0);
gap> EvaluateBySCSCP( "WS_Factorial", [10], "localhost", 26133 : output:="cookie" );
rec( attributes := [ [ "call_id", "localhost:26133:2442:jNQG6rml" ] ],
      object := < remote object scscp://localhost:26133/TEMPVarSCSCP5KZieiKD > )
gap> EvaluateBySCSCP( "WS_Factorial", [10], "localhost", 26133 : output:="nothing" );
rec( attributes := [ [ "call_id", "localhost:26133:2442:9QHQRcjv" ] ],
```

```
object := "procedure completed" )
```

Now we demonstrate the procedure `GroupIdentificationService`, also given in the previous chapter:

Example

```
gap> G:=SymmetricGroup(4);
Sym( [ 1 .. 4 ] )
gap> gens:=GeneratorsOfGroup(G);
[ (1,2,3,4), (1,2) ]
gap> EvaluateBySCSCP( "GroupIdentificationService", [ gens ],
> "localhost", 26133 : debuglevel:=3 );
rec( attributes := [ [ "call_id", "localhost:26133:2442:x0ilXtnw" ],
[ "info_runtime", 4 ], [ "info_memory", 2596114432 ],
[ "info_message", "Memory usage for the result is 48 bytes" ] ],
object := [ 24, 12 ] )
```

Service provider may suggest to the client to use a counterpart function

Example

```
gap> IdGroupWS := function( G )
> local H, result;
> if not IsPermGroup(G) then
>   H:= Image( IsomorphismPermGroup( G ) );
> else
>   H := G;
> fi;
> result := EvaluateBySCSCP ( "GroupIdentificationService",
> [ GeneratorsOfGroup(H) ], "localhost", 26133 );
> return result.object;
> end;;
```

which works exactly like `IdGroup` (**smallgrp: IdGroup**):

Example

```
gap> G:=DihedralGroup(64);
<pc group of size 64 with 6 generators>
gap> IdGroupWS(G);
[ 64, 52 ]
```

6.4 Switching between Binary and XML OpenMath Encodings

6.4.1 SwitchSCSCPmodeToBinary

▷ `SwitchSCSCPmodeToBinary()`

(function)

▷ `SwitchSCSCPmodeToXML()`

(function)

Returns: nothing

The `OpenMath` package supports both binary and XML encodings for `OpenMath`. To switch between them, use `SwitchSCSCPmodeToBinary` and `SwitchSCSCPmodeToXML`. When the package is loaded, the mode is initially set to XML. On the clients's side, you can change the mode back and forth as many times as you wish during the same `SCSCP` session. The server will autodetect the mode and will response in the same format, so one does not need to set the mode on the server's side.

For example, let us create a vector over $GF(3)$:

Example

```
gap> x := [ Z(3)^0, Z(3), 0*Z(3) ];
[ Z(3)^0, Z(3), 0*Z(3) ]
```

The XML `OpenMath` encoding of such objects is quite bulky:

Example

```
gap> OMPrint( x );
<OMOBJ xmlns="http://www.openmath.org/OpenMath" version="2.0">
  <OMA>
    <OMS cd="list1" name="list"/>
    <OMA>
      <OMS cd="arith1" name="power"/>
      <OMA>
        <OMS cd="finfield1" name="primitive_element"/>
        <OMI>3</OMI>
      </OMA>
      <OMI>0</OMI>
    </OMA>
    <OMA>
      <OMS cd="arith1" name="power"/>
      <OMA>
        <OMS cd="finfield1" name="primitive_element"/>
        <OMI>3</OMI>
      </OMA>
      <OMI>1</OMI>
    </OMA>
    <OMA>
      <OMS cd="arith1" name="times"/>
      <OMA>
        <OMS cd="finfield1" name="primitive_element"/>
        <OMI>3</OMI>
      </OMA>
      <OMI>0</OMI>
    </OMA>
  </OMA>
</OMOBJ>
gap> Length( OMString(x) );
507
```

We call the `SCSCP` procedure `Identity` just to test how this object may be sent back and forth. The total length of the procedure call message is 969 symbols:

Example

```

gap> SetInfoLevel(InfoSCSCP,3);
gap> EvaluateBySCSCP("Identity",[x],"localhost",26133);
#I Creating a socket ...
#I Connecting to a remote socket via TCP/IP ...
#I Got connection initiation message
#I <?scscp service_name="GAP" service_version="4.dev" service_id="localhost:2\
6133:42448" scscp_versions="1.0 1.1 1.2 1.3" ?>
#I Requesting version 1.3 from the server ...
#I Server confirmed version 1.3 to the client ...
#I Composing procedure_call message:
<?scscp start ?>
<OMOBJ xmlns="http://www.openmath.org/OpenMath" version="2.0">
  <OMATTR>
    <OMATP>
      <OMS cd="scscp1" name="call_id"/>
      <OMSTR>localhost:26133:42448:IOs9ZkBU</OMSTR>
      <OMS cd="scscp1" name="option_return_object"/>
      <OMSTR></OMSTR>
    </OMATP>
    <OMA>
      <OMS cd="scscp1" name="procedure_call"/>
      <OMA>
        <OMS cd="scscp_transient_1" name="Identity"/>
        <OMA>
          <OMS cd="list1" name="list"/>
          <OMA>
            <OMS cd="arith1" name="power"/>
            <OMA>
              <OMS cd="finfield1" name="primitive_element"/>
              <OMI>3</OMI>
            </OMA>
            <OMI>0</OMI>
          </OMA>
          <OMA>
            <OMS cd="arith1" name="power"/>
            <OMA>
              <OMS cd="finfield1" name="primitive_element"/>
              <OMI>3</OMI>
            </OMA>
            <OMI>1</OMI>
          </OMA>
          <OMA>
            <OMS cd="arith1" name="times"/>
            <OMA>
              <OMS cd="finfield1" name="primitive_element"/>
              <OMI>3</OMI>
            </OMA>
            <OMI>0</OMI>
          </OMA>
        </OMA>
      </OMA>
    </OMA>
  </OMATTR>
</OMOBJ>

```

```

    </OMA>
  </OMATTR>
</OMOBJ>
<?scscp end ?>
#I Total length 969 characters
...
rec( attributes := [ [ "call_id", "localhost:26133:42448:IOs9ZkBU" ] ],
      object := [ Z(3)^0, Z(3), 0*Z(3) ] )

```

Now we switch to binary mode:

Example

```

gap> SwitchSCSCPmodeToBinary();
gap> EvaluateBySCSCP("Identity", [x], "localhost", 26133);
#I Creating a socket ...
#I Connecting to a remote socket via TCP/IP ...
#I Got connection initiation message
#I <?scscp service_name="GAP" service_version="4.dev" service_id="localhost:2\
6133:42448" scscp_versions="1.0 1.1 1.2 1.3" ?>
#I Requesting version 1.3 from the server ...
#I Server confirmed version 1.3 to the client ...
#I Composing procedure_call message:
3C3F7363736370207374617274203F3E0A18121408060773637363703163616C6C5F6964061E6C\
6F63616C686F73743A32363133333A34323434383A3256675A5562755A0806147363736370316F\
7074696F6E5F72657475726E5F6F626A6563740600151008060E73637363703170726F63656475\
72655F63616C6C1008110873637363705F7472616E7369656E745F314964656E74697479100805\
046C697374316C69737410080605617269746831706F7765721008091166696E6669656C643170\
72696D69746976655F656C656D656E7401031101001110080605617269746831706F7765721008\
091166696E6669656C64317072696D69746976655F656C656D656E740103110101111008060561\
726974683174696D65731008091166696E6669656C64317072696D69746976655F656C656D656E\
7401031101001111111113193C3F736373637020656E64203F3E0A
#I Total length 339 bytes
#I Request sent ...
#I Waiting for reply ...
#I <?scscp start ?>
#I Got back: object [ Z(3)^0, Z(3), 0*Z(3) ] with attributes
[ [ "call_id", "localhost:26133:42448:2VgZUbuZ" ] ]
rec( attributes := [ [ "call_id", "localhost:26133:42448:2VgZUbuZ" ] ],
      object := [ Z(3)^0, Z(3), 0*Z(3) ] )
gap> SetInfoLevel(InfoSCSCP,3);

```

As we can see, the size of the message is almost three times shorter, and this is not the limit. Switching to binary **OpenMath** encoding in combination with pickling and unpickling from **IO** package (see in the last Chapter) and special methods for pickling compressed vectors implemented in the **Cvec** available in **GAP 4.5** allow to dramatically reduce the overhead for vectors and matrices over finite fields, making a roundtrip up to a thousand times faster.

6.5 Remote objects

The SCSCP package introduces new kind of objects – *remote objects*. They provide an opportunity to manipulate with objects on remote services without their actual transmitting over the network. Remote objects store the information that allows to access the original object: the server name and the port number through which the object can be accessed, and the variable name under which it is stored in the remote system. Two remote objects are equal if and only if all these three parameters coincide.

There are two types of remote object which differ by their lifetime:

- temporary remote objects which exist only within a single session;
- persistent remote objects which stay alive across multiple sessions.

First we show the example of the temporary remote object in a session. The procedure `PointImages` returns the set of images of a point i under the generators of the group G . First we create the symmetric group S_3 on the client and store it remotely on the server (call 1), then we compute set of images for $i = 1, 2$ (calls 2,3) and finally demonstrate that we may retrieve the group from the server (call 4):

Example

```
gap> stream:=InputOutputTCPStream( "localhost", 26133 );
< input/output TCP stream to localhost:26133 >
gap> StartSCSCPsession(stream);
"localhost:26133:6184"
gap> OMPutProcedureCall( stream, "store_session",
>   rec( object := [ SymmetricGroup(3) ],
>   attributes := [ [ "call_id", "1" ],
>   ["option_return_cookie" ] ] ) );
true
gap> SCSCPwait( stream );
gap> G:=OMGetObjectWithAttributes( stream ).object;
< remote object scscp://localhost:26133/TEMPVarSCSCPo3Bc8J75 >
gap> OMPutProcedureCall( stream, "PointImages",
>   rec( object := [ G, 1 ],
>   attributes := [ [ "call_id", "2" ] ] ) );
true
gap> SCSCPwait( stream );
gap> OMGetObjectWithAttributes( stream );
rec( attributes := [ [ "call_id", "2" ] ], object := [ 2 ] )
gap> OMPutProcedureCall( stream, "PointImages",
>   rec( object := [ G, 2 ],
>   attributes := [ [ "call_id", "3" ] ] ) );
true
gap> SCSCPwait( stream );
gap> OMGetObjectWithAttributes( stream );
rec( attributes := [ [ "call_id", "3" ] ], object := [ 1, 3 ] )
gap> OMPutProcedureCall( stream, "retrieve",
>   rec( object := [ G ],
>   attributes := [ [ "call_id", "4" ] ] ) );
true
gap> SCSCPwait( stream );
gap> OMGetObjectWithAttributes( stream );
rec( attributes := [ [ "call_id", "4" ] ],
```

```

object := Group([ (1,2,3), (1,2) ]) )
gap> CloseStream(stream);

```

After the stream is closed, it is no longer possible to retrieve the group G again or use it as an argument.

Thus, the usage of remote objects existing during a session reduces the network traffic, since we pass only references instead of actual **OpenMath** representation of an object. Also, the remote object on the server may accumulate certain information in its properties and attributes, which may not be included in its default **OpenMath** representation.

Now we show remote objects which remain alive after the session is closed. Such remote objects may be accessed later, for example, by:

- subsequent procedure calls from the same instance of **GAP** or another system;
- other instances of **GAP** or another systems (if the identifier of an object is known)
- another SCSCP servers which obtained a reference to such object as an argument of a procedure call.

6.5.1 StoreAsRemoteObjectPersistently

▷ StoreAsRemoteObjectPersistently(obj, server, port) (function)
 ▷ StoreAsRemoteObject(obj, server, port) (function)

Returns: remote object

Returns the remote object corresponding to the object created at `server:port` from the **OpenMath** representation of the first argument `obj`. The second form is just a synonym.

Example

```

gap> s:=StoreAsRemoteObject( SymmetricGroup(3), "localhost", 26133 );
< remote object scscp://localhost:26133/TEMPVarSCSCPLvIUUtL3 >

```

Internally, the remote object carries all the information which is required to get access to the original object: its identifier, server and port:

Example

```

gap> s![1];
"TEMPVarSCSCPLvIUUtL3"
gap> s![2];
"localhost"
gap> s![3];
26133

```

When the remote object is printed in the **OpenMath** format, we use symbols @ and : to combine these parameters in the **OpenMath** reference:

Example

```

gap> OMPrint(s);
<OMOBJ>

```

```
<OMR href="scscp://localhost:26133/TEMPVarSCSCPLvIUUtL3" />
</OMOBJ>
```

This allows substitution of remote object as arguments into procedure calls in the same manner like we do this with usual objects:

Example

```
gap> EvaluateBySCSCP("WS_IdGroup",[s],"localhost",26133);
rec( attributes := [ [ "call_id", "localhost:26133:52918:Viq6EWBP" ] ],
      object := [ 6, 1 ] )
```

6.5.2 IsRemoteObject

▷ IsRemoteObject

(filter)

This is the category of remote objects.

6.5.3 RemoteObjectsFamily

▷ RemoteObjectsFamily

(family)

This is the family of remote objects.

6.5.4 RetrieveRemoteObject

▷ RetrieveRemoteObject(*remoteobject*)

(function)

Returns: object

This function retrieves the remote object from the remote service in the OpenMath format and constructs it locally. Note, however, that for a complex mathematical object its default OpenMath representation may not contain all information about it which was accumulated during its lifetime on the SCSCP server.

Example

```
gap> RetrieveRemoteObject(s);
Group([ (1,2,3), (1,2) ])
```

6.5.5 UnbindRemoteObject

▷ UnbindRemoteObject(*remoteobject*)

(function)

Returns: true or false

Removes any value currently bound to the global variable determined by *remoteobject* at the SCSCP server, and returns true or false depending on whether this action was successful or not.

Example

```
gap> UnbindRemoteObject(s);
true
```

Finally, we show an example when first we create a group on the service running on port 26133, and then identify it on the service running on port 26134:

Example

```
gap> s:=StoreAsRemoteObject( SymmetricGroup(3), "localhost", 26133 );
< remote object scscp://localhost:26133/TEMPVarSCSCPnqc8Bkan >
gap> EvaluateBySCSCP( "WS_IdGroup", [ s ], "localhost", 26134 );
rec( object := [ 6, 1 ], attributes := [ [ "call_id", "localhost:26134:7414" ] ] )
```

Instead of transmitting the group to the client and then sending it as an argument to the second service, the latter service directly retrieves the group from the first service:

Example

```
gap> EvaluateBySCSCP("WS_IdGroup",[s],"localhost",26133 : output="cookie" );
rec( attributes := [ [ "call_id", "localhost:26133:52918:mRU6w471" ] ],
      object := < remote object scscp://localhost:26133/TEMPVarSCSCPS9SVe9PZ > )
```

Chapter 7

Examples of SCSCP usage

In this chapter we are going to demonstrate some examples of communication between client and server using the SCSCP.

7.1 Providing services with the SCSCP package

You can try to run the SCSCP server with the configuration file `scscp/example/myserver.g`. To do this, go to that directory and enter `gap myserver.g`. After this you will see some information messages and finally the server will start to wait for the connection. The final part of the startup screen may look as follows:

Example

```
#I Installed SCSCP procedure Factorial
#I Installed SCSCP procedure WS_Factorial
#I Installed SCSCP procedure GroupIdentificationService
#I Installed SCSCP procedure IdGroup512ByCode
#I Installed SCSCP procedure WS_IdGroup
#I Installed SCSCP procedure WS_Karatsuba
#I Installed SCSCP procedure EvaluateOpenMathCode
#I Ready to accept TCP/IP connections at localhost:26133 ...
#I Waiting for new client connection at localhost:26133 ...
```

See further self-explanatory comments in the file `scscp/example/myserver.g`. There also some test files in the directory `scscp/tst/` supplied with detailed comments. First, you may use demonstration files, preliminary turning on the demonstration mode as it is explained in these files, or just executing step by step each command from `scscp/tst/demo.g` and `scscp/tst/omdemo.g`. Then you can try to use files `scscp/tst/id512.g`, `scscp/tst/idperm.g` and `scscp/tst/factor.g` for further tests of SCSCP services.

7.2 Identifying groups of order 512

We will give an example guiding you through all steps of creation of your own SCSCP service.

The GAP Small Group Library does not provide identification for groups of order 512 using the function `IdGroup`:

Example

```
gap> IdGroup( DihedralGroup( 256 ) );
[ 256, 539 ]
gap> IdGroup(DihedralGroup(512));
Error, the group identification for groups of size 512 is not available
called from
<function "unknown">( <arguments> )
  called from read-eval loop at line 71 of *stdin*
you can 'quit;' to quit to outer loop, or
you can 'return;' to continue
brk>
```

However, the GAP package ANUPQ [GNOH] has a function `IdStandardPresented512Group` that does this work as demonstrated below:

Example

```
gap> LoadPackage("anupq", false);
true
gap> G := DihedralGroup( 512 );
<pc group of size 512 with 9 generators>
gap> F := PqStandardPresentation( G );
<fp group on the generators [ f1, f2, f3, f4, f5, f6, f7, f8, f9 ]>
gap> H := PcGroupFpGroup( F );
<pc group of size 512 with 9 generators>
gap> IdStandardPresented512Group( H );
[ 512, 2042 ]
```

The package ANUPQ requires UNIX environment and it is natural to provide an identification service for groups of order 512 to make it available for other platforms.

Now we need to decide how the client will transmit a group to the server. Can we encode this group in OpenMath? But there is no content dictionary for PcGroups. Should we convert it to a permutation representation to be able to use existing content dictionaries? But then the resulting OpenMath code will be not compact. However, the SCSCP protocol provides enough freedom for the user to select its own data representation, and since we are linking together two copies of the same system, we may use the *pcgs code* to pass the data to the server (see `CodePcGroup` (**Reference: CodePcGroup**)).

First we create a function which accepts the integer number that is the code for pcgs of a group of order 512 and returns the number of this group in the GAP Small Groups library:

Example

```
IdGroup512ByCode := function( code )
local G, F, H;
G := PcGroupCode( code, 512 );
F := PqStandardPresentation( G );
H := PcGroupFpGroup( F );
return IdStandardPresented512Group( H );
end;
```

After such function was created on the server, we need to make it “visible” as an SCSCP procedure:

Example

```
gap> InstallSCSCPprocedure("IdGroup512", IdGroup512ByCode );
InstallSCSCPprocedure : procedure IdGroup512 installed.
```

Note that this function assumes that the argument is a valid code for some group of order 512, and we wish the client to make it sure that this is the case. To do this, and also for the client’s convenience, we provide the client’s counterpart for this service. Here the group must be a pc-group of order 512, otherwise an error message will appear.

Example

```
gap> IdGroup512 := function( G )
>   local code, result;
>   if Size( G ) <> 512 then
>     Error( "G must be a group of order 512 \n" );
>   fi;
>   code := CodePcGroup( G );
>   result := EvaluateBySCSCP( "IdGroup512ByCode", [ code ],
>                             "localhost", 26133 );
>   return result.object;
> end;;
```

Now the client can call the function `IdGroup512`, and the procedure of getting result is as much straightforward as using `IdGroup` for those groups where it works:

Example

```
gap> IdGroup512(DihedralGroup(512));
[ 512, 2042 ]
```

Chapter 8

Parallel computing with SCSCP

8.1 Managing multiple requests

Using procedure calls explained in the previous section, the user can create several requests to multiple services to execute them in parallel, or to wait until the fastest result will be available.

8.1.1 SynchronizeProcesses

▷ `SynchronizeProcesses(process1, process2, ..., processN)` (function)

▷ `SynchronizeProcesses(proclist)` (function)

Returns: list of records with components `object` and `attributes`

The function collects results of from each process given in the argument, and returns the list, i -th entry of which is the result obtained from the i -th process. The function accepts both one argument that is a list of processes, and arbitrary number of arguments, each of them being a process.

Example

```
gap> a:=NewProcess( "WS_Factorial", [10], "localhost", 26133 );
< process at localhost:26133 pid=2064 >
gap> b:=NewProcess( "WS_Factorial", [20], "localhost", 26134 );
< process at localhost:26134 pid=1975 >
gap> SynchronizeProcesses(a,b);
[ rec( attributes := [ [ "call_id", "localhost:26133:2064:yCWBGYFO" ] ],
  object := 3628800 ),
  rec( attributes := [ [ "call_id", "localhost:26134:1975:yAAWvGTL" ] ],
  object := 2432902008176640000 ) ]
```

8.1.2 FirstProcess

▷ `FirstProcess(process1, process2, ..., processN)` (function)

▷ `FirstProcess(proclist)` (function)

Returns: records with components `object` and `attributes`

The function waits for the result from each process given in the argument, and returns the result coming first, terminating all remaining processes at the same time. The function accepts both one argument that is a list of processes, and arbitrary number of arguments, each of them being a process.

Example

```
gap> a:=NewProcess( "WS_Factorial", [10], "localhost", 26133 );
< process at localhost:26133 pid=2064 >
gap> b:=NewProcess( "WS_Factorial", [20], "localhost", 26134 );
< process at localhost:26134 pid=1975 >
gap> FirstProcess(a,b);
rec( attributes := [ [ "call_id", "localhost:26133:2064:mdb8Ra02" ] ],
      object := 3628800 )
```

8.1.3 SCSCPservers

▷ SCSCPservers

(global variable)

SCSCPservers is a list of hosts and ports to search for SCSCP services (which may be not only represented by GAP services, but also by another SCSCP-compliant systems).

It is used by parallel skeletons ParQuickWithSCSCP (8.1.4) and ParListWithSCSCP (8.2.1).

The initial value of this variable is specified in the file `scscp/configpar.g` and may be reassigned later.

8.1.4 ParQuickWithSCSCP

▷ ParQuickWithSCSCP(*commands*, *listargs*)

(function)

Returns: record with components *object* and *attributes*

This function is constructed using the FirstProcess (8.1.2). It is useful when it is not known which particular method is more efficient, because it allows to call in parallel several procedures (given by the list of their names *commands*) with the same list of arguments *listargs* (having the same meaning as in EvaluateBySCSCP (6.3.1)) and obtain the result of that procedure call which will be computed faster.

In the example below we call two factorisation methods from the GAP package FactInt to factorise $2^{150} + 1$. The example is selected in such a way that the runtime of these two methods is approximately the same, so you should expect results from both methods in some random order from repeated calls.

Example

```
gap> ParQuickWithSCSCP( [ "WS_FactorsECM", "WS_FactorsMPQS" ], [ 2^150+1 ] );
rec( attributes := [ [ "call_id", "localhost:26133:53877:GQX8MhC8" ] ],
      object := [ [ 5, 5, 5, 13, 41, 61, 101, 1201, 1321, 63901 ],
                  [ 2175126601, 15767865236223301 ] ] )
```

8.1.5 FirstTrueProcess

▷ FirstTrueProcess(*process1*, *process2*, ..., *processN*)

(function)

▷ FirstTrueProcess(*proclist*)

(function)

Returns: list of records

The function waits for the result from each process given in the argument, and stops waiting as soon as the first true is returned, abandoning all remaining processes. It returns a list containing a

records with components `object` and `attributes` at the position corresponding to the process that returned `true`. If none of the processes returned `true`, it will return a complete list of procedure call results.

The function accepts both one argument that is a list of processes, and arbitrary number of arguments, each of them being a process.

In the first example, the second call returns `true`:

Example

```
gap> a:=NewProcess( "IsPrimeInt", [2^15013-1], "localhost", 26134 );
< process at localhost:26134 pid=42554 >
gap> b:=NewProcess( "IsPrimeInt", [2^521-1], "localhost", 26133 );
< process at localhost:26133 pid=42448 >
gap> FirstTrueProcess(a,b);
[ , rec( attributes := [ [ "call_id", "localhost:26133:42448:Lz1DL00N" ] ],
    object := true ) ]
```

In the next example both calls return `false`:

Example

```
gap> a:=NewProcess( "IsPrimeInt", [2^520-1], "localhost", 26133 );
< process at localhost:26133 pid=42448 >
gap> b:=NewProcess( "IsPrimeInt", [2^15013-1], "localhost", 26134 );
< process at localhost:26134 pid=42554 >
gap> FirstTrueProcess(a,b);
[ rec( attributes := [ [ "call_id", "localhost:26133:42448:nvsk8PQp" ] ],
    object := false ),
  rec( attributes := [ [ "call_id", "localhost:26134:42554:JnEYuXL8" ] ],
    object := false ) ]
```

8.2 MasterWorker skeleton

In this section we will present more general framework to run parallel computations, which has a number of useful features:

- it is implemented purely in GAP;
- the client (i.e. master, which orchestrates the computation) will work in UNIX/Linux, Mac OS X and MS Windows;
- it may orchestrate both GAP and non-GAP SCSCP servers;
- if one of servers (i.e. workers) will be lost, it will retry the computation on another available server;
- it allows to add dynamically new workers during the computation on hostnames and ports from a range previously declared in SCSCP servers (8.1.3).

To configure this functionality, the file `scscp/configpar.g` assigns the global variable `SCSCPservers` which specifies a list of hosts and ports to search for SCSCP services (which may be not only represented by GAP services, but also by another SCSCP-compliant systems). See comments in this file for further instructions.

8.2.1 ParListWithSCSCP

▷ `ParListWithSCSCP(listargs, procname)` (function)

Returns: list

`ParListWithSCSCP` implements the well-known master-worker skeleton: we have a master (SCSCP client) and a number of workers (SCSCP servers) which obtain pieces of work from the client, perform the required job and report back with the result, waiting for the next job.

It returns the list of the same length as `listargs`, *i*-th element of which is the result of calling the procedure `procname` with the argument `listargs[i]`.

It accepts two options which should be given as non-negative integers: `timeout` which specifies in minutes how long the client must wait for the result (if not given, the default value is one hour) and `recallfrequency` which specifies the number of iterations after which the search for new services will be performed (if not given the default value is zero meaning no such search at all). There is also a boolean option `noretry` which, if set to true, means that no retrying calls will be performed if the timeout is exceeded and an incomplete result may be returned.

Example

```
gap> ParListWithSCSCP( List( [2..6], n -> SymmetricGroup(n)), "WS_IdGroup" );
#I master -> [ "localhost", 26133 ] : SymmetricGroup( [ 1 .. 2 ] )
#I master -> [ "localhost", 26134 ] : SymmetricGroup( [ 1 .. 3 ] )
#I [ "localhost", 26133 ] --> master : [ 2, 1 ]
#I master -> [ "localhost", 26133 ] : SymmetricGroup( [ 1 .. 4 ] )
#I [ "localhost", 26134 ] --> master : [ 6, 1 ]
#I master -> [ "localhost", 26134 ] : SymmetricGroup( [ 1 .. 5 ] )
#I [ "localhost", 26133 ] --> master : [ 24, 12 ]
#I master -> [ "localhost", 26133 ] : SymmetricGroup( [ 1 .. 6 ] )
#I [ "localhost", 26133 ] --> master : [ 720, 763 ]
#I [ "localhost", 26134 ] --> master : [ 120, 34 ]
[ [ 2, 1 ], [ 6, 1 ], [ 24, 12 ], [ 120, 34 ], [ 720, 763 ] ]
```

8.2.2 SCSCPreset

▷ `SCSCPreset()` (function)

Returns: nothing

If an error occurs during a call of `ParQuickWithSCSCP` (8.1.4) and `ParListWithSCSCP` (8.2.1), some of parallel requests may be still running at the remaining services, making them inaccessible for further procedure calls. `SCSCPreset` resets them by closing all open streams to SCSCP servers.

8.2.3 SCSCPLogTracesToGlobal

▷ `SCSCPLogTracesToGlobal(testname)` (function)

▷ `SCSCPLogTracesToGlobal()` (function)

To analyse the performance of parallel SCSCP framework, we make use of the **EdenTV** program [BL07] developed initially to visualize the performance of parallel programs written in functional programming language Eden, and now distributed under the GNU Public License and available from <http://www.mathematik.uni-marburg.de/~eden/?content=EdenTV>.

Called with the string containing the name of the test, this functions turns on writing information about key activity events into trace files in current directories for the client and servers listed `SCSCP`servers (8.1.3). The trace file will have the name of the format `testname.client.tr` for the client and `testname.<hostname>.<port>.tr` for the server. After the test these files should be collected from remote servers and concatenated (e.g. using `cat`) together with the standard preamble from the file `scscp/tracing/stdhead.txt` (we recommend to put after the preamble first all traces from servers and then the client's traces to have nicer diagrams). The resulting file then may be opened with **EdenTV**.

In the following example we use a dual core MacBook laptop to generate trace files for two tests and then show their corresponding trace diagrams:

Example

```
SCSCPLogTracesToGlobal("quillen100");
ParListWithSCSCP( List( [1..100], i->[512,i]), "QuillenSeriesByIdGroup" );
SCSCPLogTracesToGlobal();
SCSCPLogTracesToGlobal( "euler" );
ParListWithSCSCP( [1..1000], "WS_Phi" );
SCSCPLogTracesToGlobal();
```





The diagrams (made on an dual core MacBook laptop), shows that in the first case parallelising is efficient and master successfully distributes load to workers, while in the second case a single computation is just too short, so most of the time is spent on communication. To parallelize the Euler's function example efficiently, tasks must rather be grouped in chunks, which should be enough large to reduce the communication overload, but enough small to ensure that tasks are evenly distributed.

Of course, tracing can be used to investigate communication between a client and a single server in a non-parallel context as well. For this purpose, `SCSCP`servers (8.1.3) must be modified to contain only one server.

`ParListWithSCSCP` (8.2.1) can be easily modified to have parallel versions of other list operations like `ForAll` (**Reference: ForAll**), `ForAny` (**Reference: ForAny**), `First` (**Reference: First**), `Number` (**Reference: Number**), `Filtered` (**Reference: Filtered**), and also to have the skeleton in which the queue may be modified during the computation (for example, to compute orbits). We plan to provide such tools in one of the next versions of the package.

8.3 Example: parallelising Karatsuba multiplication for polynomials

The file `scscp/example/karatsuba.g` contains an implementation of the Karatsuba multiplication algorithm for polynomials. This algorithm can be easily parallelized since each recursive step creates three recursive calls of the same function for other polynomials. *We will not parallelize each recursive call*, since this will create enormous data flow. Instead of this we parallelize only the top-level function. For our experiments with parallelising Karatsuba multiplication for polynomials with integer coefficients we used the multi-core workstation, on which we started one `SCSCP` client and two `SCSCP` servers. To use it, modify the server configuration file adding to it the command to read the file `scscp/example/karatsuba.g`, then define there the following function

Example

```
KaratsubaPolynomialMultiplicationExtRepByString:=function(s1,s2)
  return String( KaratsubaPolynomialMultiplicationExtRep(
    EvalString(s1), EvalString(s2) ) );
end;;
```

and finally add the following lines to make it available as an SCSCP procedure under the name WS_Karatsuba:

Example

```
InstallSCSCPprocedure( "WS_Karatsuba",
  KaratsubaPolynomialMultiplicationExtRepByString);
```

(we do not include it into the default `scscp/example/myserver.g` since the code contains a call to `EvalString` (**Reference: EvalString**)).

This function provides a "bridge" between the client's function `KaratsubaPolynomialMultiplicationWS` and the server's function `KaratsubaPolynomialMultiplicationExtRep`, which performs the actual work on the server. `WS_Karatsuba` converts its string arguments into internal representation of univariate polynomials (basically, lists of integers) and then converts the result back into string (since such data exchange format was chosen).

We are going to parallelize the following part of the client's code:

Example

```
...
u := KaratsubaPolynomialMultiplicationExtRep(f1,g1);
v := KaratsubaPolynomialMultiplicationExtRep(f0,g0);
w := KaratsubaPolynomialMultiplicationExtRep(
    PlusLaurentPolynomialsExtRep(f1,f0),
    PlusLaurentPolynomialsExtRep(g1,g0) );
...
```

and this can be done straightforwardly – we replace two first calls by calls of the appropriate SCSCP services, then perform the 3rd call locally and then collect the results from the two remote calls:

Example

```
...
u := NewProcess( "WS_Karatsuba",[ String(f1), String(g1) ],"localhost", 26133);
v := NewProcess( "WS_Karatsuba",[ String(f0), String(g0) ],"localhost", 26134);
w := KaratsubaPolynomialMultiplicationExtRep(
    PlusLaurentPolynomialsExtRep(f1,f0),
    PlusLaurentPolynomialsExtRep(g1,g0) );
wsresult:=SynchronizeProcesses2( u,v );
u := EvalString( wsresult[1].object );
v := EvalString( wsresult[2].object );
...
```

We obtain almost double speedup on three cores on randomly generated polynomials of degree 32000:

Example

```
gap> ReadPackage("scscp", "example/karatsuba.g");
true
gap> fam:=FamilyObj(1);
gap> f:=LaurentPolynomialByCoefficients( fam,
> List([1..32000],i->Random(Integers)), 0, 1 );
gap> g:=LaurentPolynomialByCoefficients( fam,
> List([1..32000],i->Random(Integers)), 0, 1 );
gap> t2:=KaratsubaPolynomialMultiplication(f,g);;time;
5892
gap> t3:=KaratsubaPolynomialMultiplicationWS(f,g);;time;
2974
```

Chapter 9

Service functions

9.1 Pinging SCSCP servers

9.1.1 PingSCSCPservice

▷ `PingSCSCPservice(hostname, portnumber)` (function)

Returns: true or fail

This function returns true if the client can establish connection with the SCSCP server at `hostname:portnumber`. Otherwise, it returns fail.

Example

```
gap> PingSCSCPservice("localhost",26133);
true
gap> PingSCSCPservice("localhost",26140);
Error: rec(
  message := "Connection refused",
  number := 61 )
fail
```

9.1.2 PingStatistic

▷ `PingStatistic(hostname, portnumber, n)` (function)

Returns: nothing

The function is similar to the UNIX ping. It tries `n` times to establish connection with the SCSCP server at `hostname:portnumber`, and then displays statistical information.

Example

```
gap> PingStatistic("localhost",26133,1000);
1000 packets transmitted, 1000 received, 0% packet loss, time 208ms
min/avg/max = [ 0, 26/125, 6 ]
```


9.2 Info classes for SCSCP

9.2.1 InfoSCSCP

▷ InfoSCSCP

(info class)

InfoSCSCP is a special Info class for the SCSCP package. The amount of information to be displayed can be specified by the user by setting InfoLevel for this class from 0 to 4, and the default value of InfoLevel for the package is specified in the file `scscp/config.g`. The higher the level is, the more information will be displayed. To change the InfoLevel to `k`, use the command `SetInfoLevel(InfoSCSCP, k)`. In the following examples we demonstrate various degrees of output details using Info messages.

Default Info level:

Example

```
gap> SetInfoLevel(InfoSCSCP,2);
gap> EvaluateBySCSCP( "WS_Factorial",[10],"localhost",26133);
#I Creating a socket ...
#I Connecting to a remote socket via TCP/IP ...
#I Got connection initiation message
#I <?scscp service_name="GAP" service_version="4.dev" service_id="localhost:2\
6133:286" scscp_versions="1.0 1.1 1.2 1.3" ?>
#I Requesting version 1.3 from the server ...
#I Server confirmed version 1.3 to the client ...
#I Request sent ...
#I Waiting for reply ...
#I <?scscp start ?>
#I <?scscp end ?>
#I Got back: object 3628800 with attributes
[ [ "call_id", "localhost:26133:286:JL6KRQeh" ] ]
rec( attributes := [ [ "call_id", "localhost:26133:286:JL6KRQeh" ] ],
      object := 3628800 )
```

Minimal Info level:

Example

```
gap> SetInfoLevel(InfoSCSCP,0);
gap> EvaluateBySCSCP( "WS_Factorial",[10],"localhost",26133);
rec( attributes := [ [ "call_id", "localhost:26133:286:jzjsp6th" ] ],
      object := 3628800 )
```

Verbose Info level:

Example

```
gap> SetInfoLevel(InfoSCSCP,3);
gap> EvaluateBySCSCP( "WS_Factorial",[10],"localhost",26133);
#I Creating a socket ...
#I Connecting to a remote socket via TCP/IP ...
#I Got connection initiation message
#I <?scscp service_name="GAP" service_version="4.dev" service_id="localhost:2\
```

```

6133:286" scscp_versions="1.0 1.1 1.2 1.3" ?>
#I Requesting version 1.3 from the server ...
#I Server confirmed version 1.3 to the client ...
#I Composing procedure_call message:
<?scscp start ?>
<OMOBJ xmlns="http://www.openmath.org/OpenMath" version="2.0">
  <OMATTR>
    <OMATP>
      <OMS cd="scscp1" name="call_id"/>
      <OMSTR>localhost:26133:286:Jok6cQAf</OMSTR>
      <OMS cd="scscp1" name="option_return_object"/>
      <OMSTR></OMSTR>
    </OMATP>
    <OMA>
      <OMS cd="scscp1" name="procedure_call"/>
      <OMA>
        <OMS cd="scscp_transient_1" name="WS_Factorial"/>
        <OMI>10</OMI>
      </OMA>
    </OMA>
  </OMATTR>
</OMOBJ>
<?scscp end ?>
#I Total length 396 characters
#I Request sent ...
#I Waiting for reply ...
#I <?scscp start ?>
#I Received message:
<OMOBJ xmlns="http://www.openmath.org/OpenMath" version="2.0">
  <OMATTR>
    <OMATP>
      <OMS cd="scscp1" name="call_id"/>
      <OMSTR>localhost:26133:286:Jok6cQAf</OMSTR>
    </OMATP>
    <OMA>
      <OMS cd="scscp1" name="procedure_completed"/>
      <OMI>3628800</OMI>
    </OMA>
  </OMATTR>
</OMOBJ>
#I <?scscp end ?>
#I Got back: object 3628800 with attributes
[ [ "call_id", "localhost:26133:286:Jok6cQAf" ] ]
rec( attributes := [ [ "call_id", "localhost:26133:286:Jok6cQAf" ] ],
      object := 3628800 )
gap> SetInfoLevel(InfoSCSCP,0);

```

9.2.2 InfoMasterWorker

▷ InfoMasterWorker

(info class)

InfoMasterWorker is a special Info class for the Master-Worker skeleton ParListWithSCSCP (8.2.1). The amount of information to be displayed can be specified by the user by setting InfoLevel for this class from 0 to 5, and the default value of InfoLevel for the package is specified in the file scscp/config.g. The higher the level is, the more information will be displayed. To change the InfoLevel to k, use the command `SetInfoLevel(InfoMasterWorker, k)`. In the following examples we demonstrate various degrees of output details using Info messages.

Default Info level:

Example

```
gap> SetInfoLevel(InfoMasterWorker,2);
gap> ParListWithSCSCP( List( [2..6], n -> SymmetricGroup(n)), "WS_IdGroup" );
#I 1/5:master --> localhost:26133
#I 2/5:master --> localhost:26134
#I 3/5:master --> localhost:26133
#I 4/5:master --> localhost:26134
#I 5/5:master --> localhost:26133
[ [ 2, 1 ], [ 6, 1 ], [ 24, 12 ], [ 120, 34 ], [ 720, 763 ] ]
```

Minimal Info level:

Example

```
gap> SetInfoLevel(InfoSCSCP,0);
gap> SetInfoLevel(InfoMasterWorker,0);
gap> ParListWithSCSCP( List( [2..6], n -> SymmetricGroup(n)), "WS_IdGroup" );
[ [ 2, 1 ], [ 6, 1 ], [ 24, 12 ], [ 120, 34 ], [ 720, 763 ] ]
```

Verbose Info level:

Example

```
gap> SetInfoLevel(InfoMasterWorker,5);
gap> ParListWithSCSCP( List( [2..6], n -> SymmetricGroup(n)), "WS_IdGroup" );
#I 1/5:master --> localhost:26133 : SymmetricGroup( [ 1 .. 2 ] )
#I 2/5:master --> localhost:26134 : SymmetricGroup( [ 1 .. 3 ] )
#I localhost:26133 --> 1/5:master : [ 2, 1 ]
#I 3/5:master --> localhost:26133 : SymmetricGroup( [ 1 .. 4 ] )
#I localhost:26134 --> 2/5:master : [ 6, 1 ]
#I 4/5:master --> localhost:26134 : SymmetricGroup( [ 1 .. 5 ] )
#I localhost:26133 --> 3/5:master : [ 24, 12 ]
#I 5/5:master --> localhost:26133 : SymmetricGroup( [ 1 .. 6 ] )
#I localhost:26134 --> 4/5:master : [ 120, 34 ]
#I localhost:26133 --> 5/5:master : [ 720, 763 ]
[ [ 2, 1 ], [ 6, 1 ], [ 24, 12 ], [ 120, 34 ], [ 720, 763 ] ]
gap> SetInfoLevel(InfoMasterWorker,2);
```

9.3 Other SCSCP Utilities

9.3.1 DateISO8601

▷ `DateISO8601()` (function)

Returns: string

Returns the current date in the ISO-8601 YYYY-MM-DD format. This is an internal function of the package which is used by the SCSCP server to generate the transient content dictionary, accordingly to the definition of the OpenMath symbol `meta.CDDate`.

Example

```
gap> DateISO8601();  
"2017-02-05"
```

9.3.2 CurrentTimestamp

▷ `CurrentTimestamp()` (function)

Returns: string

Returns the result of the call to `date`. This is an internal function of the package which is used to add the timestamp to the SCSCP service description.

Example

```
gap> CurrentTimestamp();  
"Tue 30 Jan 2017 11:19:38 BST"
```

9.3.3 Hostname

▷ `Hostname()` (function)

Returns: string

Returns the result of the call to `hostname`. This function may be used in the configuration file `scscp/config.g` to specify that the default hostname which will be used by the SCSCP server will be detected automatically using `hostname`.

Example

```
gap> Hostname();  
"scscp.gap-system.org"
```

9.3.4 MemoryUsageByGAPinKbytes

▷ `MemoryUsageByGAPinKbytes()` (function)

Returns: integer

Returns the current volume of the memory used by **GAP** in kilobytes. This is equivalent to calling `ps -p <PID> -o vsz`, where `<PID>` is the process ID of the **GAP** process. This is an internal function of the package which is used by the SCSCP server to report its memory usage in the `info_memory` attribute when being called with the option `debuglevel=2` (see options in [EvaluateBySCSCP \(6.3.1\)](#) and [NewProcess \(6.2.2\)](#)).

Example

```
gap> MemoryUsageByGAPinKbytes();
649848
```

9.3.5 LastReceivedCallID

▷ LastReceivedCallID() (function)

Returns: string

Returns the call ID contained in the most recently received message. It may contain some useful debugging information; in particular, the call ID for the GAP SCSCP client and server contains colon-separated server name, port number, process ID and a random string.

Example

```
gap> LastReceivedCallID();
"scscp.gap-system.org:26133:77372:choDZBgA"
```

9.3.6 IO_PickleToString

▷ IO_PickleToString(obj) (function)

Returns: string containing "pickled" object

This function "pickles" or "serialises" the object *obj* using the operation `IO_Pickle` (**IO: IO_Pickle**) from the `IO` package, and writes it to a string, from which it could be later restored using `IO_UnpickleFromString` (9.3.7). This provides a way to design SCSCP procedures which transmit GAP objects in the "pickled" format as `OpenMath` strings, which may be useful for objects which may be "pickled" by the `IO` package but can not be converted to `OpenMath` or for which the "pickled" representation is more compact or can be encoded/decoded much faster.

See `IO_Pickle` (**IO: IO_Pickle**) and `IO_Unpickle` (**IO: IO_Unpickle**) for more details.

Example

```
gap> f := IO_PickleToString( GF( 125 ) );
"FFIEINTG\>15INTG\>13FAIL"
```

9.3.7 IO_UnpickleFromString

▷ IO_UnpickleFromString(s) (function)

Returns: "unpickled" GAP object

This function "unpickles" the string *s* which was created using the function `IO_PickleToString` (9.3.6), using the operation `IO_Unpickle` (**IO: IO_Unpickle**) from the `IO` package. See `IO_PickleToString` (9.3.6) for more details and suggestions about its usage.

Example

```
gap> IO_UnpickleFromString( f );
GF(5^3)
gap> f = IO_UnpickleFromString( IO_PickleToString( f ) );
```

| |
|------|
| true |
|------|

References

- [BL07] Jost Berthold and Rita Loogen. Visualizing Parallel Functional Program Runs — Case Studies with the Eden Trace Viewer. In *Parallel Computing: Architectures, Algorithms and Applications. Proceedings of the International Conference ParCo 2007*, volume 15 of *Advances in Parallel Computing*. IOS Press, 2007. 44
- [CKNS] Marco Costantini, Olexandr Konovalov, Max Nicosia, and Andrew Solomon. Openmath — OpenMath functionality in GAP. GAP4 package (<https://gap-packages.github.io/openmath>). 8
- [FHK⁺a] Sebastian Freundt, Peter Horn, Olexandr Konovalov, Sylla Lesseni, Steve Linton, and Dan Roozemon. OpenMath content dictionary scscp1. (<https://openmath.org/cd/scscp1.html>). 6, 13, 17, 20
- [FHK⁺b] Sebastian Freundt, Peter Horn, Olexandr Konovalov, Sylla Lesseni, Steve Linton, and Dan Roozemon. Symbolic Computation Software Composability Protocol (SCSCP) specification, version 1.3, 2009. (<https://openmath.org/standard/scscp/>). 6, 7, 15
- [FHK⁺c] Sebastian Freundt, Peter Horn, Olexandr Konovalov, Steve Linton, and Dan Roozemon. OpenMath content dictionary scscp2. (<https://openmath.org/cd/scscp2.html>). 6, 13, 20
- [GNOH] Greg Gamble, Werner Nickel, Eamonn O’Brien, and Max Horn. ANUPQ — ANU p-Quotient. GAP4 package (<https://gap-packages.github.io/anupq/>). 38
- [LN] Frank Lübeck and Max Neunhöffer. GAPDoc — A Meta Package for GAP Documentation. GAP4 package (<https://www.math.rwth-aachen.de/~Frank.Luebeck/GAPDoc>). 8
- [Neu] Max Neunhöffer. IO — Bindings for low level C library IO. GAP4 package (<http://www-groups.mcs.st-and.ac.uk/~neunhoef/Computer/Software/Gap/io.html>). 8

Index

CloseSCSCPconnection, 26
CompleteProcess, 27
CurrentTimestamp, 52

DateISO8601, 52

EvaluateBySCSCP, 28
 for SCSCP connection, 28

FirstProcess, 40
 for list of processes, 40
FirstTrueProcess, 41
 for list of processes, 41

GetAllowedHeads, 22
GetServiceDescription, 21
GetSignature, 23
GetTransientCD, 23

Hostname, 52

InfoMasterWorker, 50
InfoSCSCP, 49
InputOutputTCPStream
 for client, 11
 for server, 11
InstallSCSCPprocedure, 18
IO_PickleToString, 53
IO_UnpickleFromString, 53
IsAllowedHead, 22
IsInputOutputTCPStream, 10
IsInputOutputTCPStreamRep, 10
IsProcess, 26
IsRemoteObject, 35
IsSCSCPconnection, 25

LastReceivedCallID, 53

MemoryUsageByGAPinKbytes, 52

NewProcess, 26
 for SCSCP connection, 26
NewSCSCPconnection, 25

OMGetObjectWithAttributes, 15
OMPutProcedureCall, 13
OMPutProcedureCompleted, 16
OMPutProcedureTerminated, 16
OMsymRecord, 20

ParListWithSCSCP, 43
ParQuickWithSCSCP, 41
PingSCSCPservice, 48
PingStatistic, 48

RemoteObjectsFamily, 35
RetrieveRemoteObject, 35
RunSCSCPserver, 20

SCSCP package, 2
SCSCPLogTracesToGlobal, 43
 to stop tracing, 43
SCSCPreset, 43
SCSCPservers, 41
SCSCPwait, 15
StartSCSCPsession, 13
StoreAsRemoteObject, 34
StoreAsRemoteObjectPersistently, 34
SwitchSCSCPmodeToBinary, 29
SwitchSCSCPmodeToXML, 29
SynchronizeProcesses, 40
 for list of processes, 40

TerminateProcess, 28

UnbindRemoteObject, 35