Objects, types and method selection in GAP

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The idea

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Properties of objects (their type)

⇓

Selection of the "right" method
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Selection of the “right” method

Objects can “learn” during their lifetime
(i.e. change their type)
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Properties of objects (their type)

_selection of the “right” method_

Objects can “learn” during their lifetime (i.e. change their type)

The methods used change as a consequence!
The idea

GAP objects represent mathematical objects. There are "operations" and "methods". Properties of objects (their type) lead to the selection of the "right" method.

Objects can "learn" during their lifetime (i.e. change their type) and the methods used change as a consequence!

GAP thus uses:
- dynamic typing at runtime
The idea

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There are “operations” and “methods”.

Properties of objects (their type)

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Selection of the “right” method

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- dynamic typing at runtime
- a static database of methods
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Selection of the "right" method  

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The methods used change as a consequence!

GAP thus uses:  
- dynamic typing at runtime  
- a static database of methods  
- "just in time" method selection
Types

A type in GAP is a pair:

(a “family”, a bit list of “elementary filters”)
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Every object o “is” either “in some given filter” or not.
This can be tested with FILTERNAME (o).
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Examples: IsSolvable, IsNilpotent, IsAbelian
Operations and methods

An operation is a collection of methods.

One declares

- the name,
- the number of arguments, and
- a filter for each argument.
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DeclareOperation("Size", [IsGroup]);
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One installs one or more methods:

- These are functions with the right number of arguments.
- One can give further restrictions:
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```
InstallMethod(Size,
    [IsGroup and IsPermGroup],
    function(p) ... return ...; end);
```
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We call these restrictions “required filters”.
The method selection

If somebody calls $\text{Size}(g)$ for an object $g$, 

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If somebody calls \texttt{Size(g)} for an object \texttt{g},

- GAP determines the \textit{type} of \texttt{g},
- considers \textit{all} methods for \texttt{Size},

This only works efficiently by a very tricky method cache!

More accurately: Each elementary filter has a "rank".

The method with the highest sum of ranks of the required filters is chosen.
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If somebody calls $\text{Size}(g)$ for an object $g$,

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- GAP determines the \textbf{type} of \( g \),
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- determines, which are \textbf{applicable} (are in all required filters),
- and calls the \textbf{method} that
  - is applicable, and
  - has the most required filters
    (if two or more have the same required filters it takes the one which was installed later).
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- determines, which are \texttt{applicable} (are in all required filters),
- and calls the \texttt{method} that
  - is \texttt{applicable}, and
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    (if two or more have the same required filters it takes the one which was installed later).

This only works efficiently by a very tricky \texttt{method cache}!

\textbf{More accurately:} Each elementary filter has a “rank”.
The method with the highest sum of ranks of the required filters is chosen.
The idea behind families

The families partition the set of all objects.
In contrast, the filters form a hierarchy of sets.
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A collection consists of objects from the same family.
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In contrast, the **filters** form a **hierarchy** of sets.

**e.g.:** `PermutationsFamily`, `CyclotomicsFamily`.

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A **collection** consists of objects from **the same family**.

One can form the “CollectionsFamily” of any family, and the “ElementsFamily” of each CollectionsFamily:
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e.g.: \texttt{PermutationsFamily}, \texttt{CyclotomicsFamily}.

For FP groups all elements of one such group form a family.

A collection consists of objects from the same family.

One can form the “CollectionsFamily” of any family, and the “ElementsFamily” of each CollectionsFamily:

\begin{verbatim}
gap> f:=CollectionsFamily(CyclotomicsFamily);;
gap> CyclotomicsFamily=ElementsFamily(f); true
gap> FamilyObj((1,2,3))=PermutationsFamily; true
\end{verbatim}
“Categories” and “representations” are nothing but elementary filters with a bit of philosophy in the background!
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Mathematically similar or equal objects can be represented differently, then they should lie in different representations.
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\textbf{IsPerm} is a category.

\textbf{IsPerm2Rep} and \textbf{IsPerm4Rep} are representations.
“Categories” and “representations” are nothing but elementary filters with a bit of philosophy in the background!

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IsPerm is a category.

IsPerm2Rep and IsPerm4Rep are representations.

Categories usually occur in declarations of operations, representations usually occur as required filters in method installations.
Inheritance in GAP

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One declares subfilters and constructs objects that lie in these additional subfilters.
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If one needs special methods, these are installed with the subfilters as additional requirements.
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One declares subfilters and constructs objects that lie in these additional subfilters.

If one needs special methods, these are installed with the subfilters as additional requirements.

Hypothetical example:

DeclareCategory("IsGroup",IsObject);
DeclareCategory("IsAbelianGroup",IsGroup);
DeclareOperation("Size",[IsGroup]);
InstallMethod(Size,"for arbitrary groups",
             [IsGroup],
             function(g) ... end);
InstallMethod(Size,"for abelian groups",
             [IsAbelianGroup],
             function(a) ... end);
The declarations

BindGlobal("BlubbsFamily",
    NewFamily("BlubbsFamily");
DeclareCategory("IsBlubb",
    IsComponentObjectRep);
DeclareRepresentation("IsBlubbDenseRep",
    IsBlubb, ["wo","p"]);
BindGlobal("BlubbDenseType",
    NewType(BlubbsFamily, IsBlubbDenseRep));

DeclaraOperation("Blubb", [IsString, IsInt]);
DeclaraOperation("IsShort", [IsBlubb]);
DeclaraOperation("NrLetters", [IsBlubb]);
InstallMethod(Blubb, "constructor",
    [IsString, IsInt], function(s, i)
    local r;
    r := rec(wo:=s, p:=i);
    return Objectify(BlubbDenseType, r);
    end);
The declarations

BindGlobal("BlubbsFamily",
    NewFamily("BlubbsFamily"));
DeclareCategory("IsBlubb",
    IsComponentObjectRep);
DeclareRepresentation("IsBlubbDenseRep",
    IsBlubb, ["wo","p"]);
BindGlobal("BlubbDenseType",
    NewType(BlubbsFamily,IsBlubbDenseRep));
DeclareOperation("Blubb", [IsString, IsInt]);
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BindGlobal("BlubbsFamily",
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InstallMethod(Blubb, "constructor",
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        local r;
        r := rec(wo:=s, p:=i);
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    end);
The implementations

InstallMethod(IsShort, "for dense Blubbs",
[IsBlubbDenseRep],
function(bl)
    return Length(bl!.wo) <= 5;
end);
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end);

InstallMethod(NrLetters,"for dense Blubbs",
[IsBlubbDenseRep],
function(bl)
    return Length(Set(bl!.wo));
end);
The implementations

InstallMethod(IsShort,"for dense Blubbs", [IsBlubbDenseRep],
  function(bl)
    return Length(bl!.wo) <= 5;
  end);

InstallMethod(NrLetters,"for dense Blubbs", [IsBlubbDenseRep],
  function(bl)
    return Length(Set(bl!.wo));
  end);

InstallMethod(ViewObj,"for dense Blubbs", [IsBlubbDenseRep],
  function(bl)
    Print("<a dense blubb wo=",bl!.wo,
      " p=",bl!.p,">");
  end);
Usage

One can now use \texttt{Blubb}-objects as follows:

\begin{verbatim}
gap> b := Blubb("abac",17);
gap> NrLetters(b);
3
gap> IsShort(b);
true

gap> b!.wo;
"abac"

gap> b!.p;
17
\end{verbatim}
Usage

One can now use **Blubb**-objects as follows:

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gap> b := Blubb("abac",17);
<a dense blubb wo=abac p=17>
gap> NrLetters(b);
3
gap> IsShort(b);
true
gap> b!.wo;
"abac"
gap> b!.p;
17
```

One should install methods for

- **ViewObj** (for the user to see a **concise** description)
- **PrintObj** (if possible **GAP**-parsable)
- and possibly **Display** (**nicely formatted** description for the user).
Properties

A Property “XYZ” is realised by:

- an elementary filter HasXYZ and
- an elementary filter XYZ.
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Properties are declared like this:
DeclareProperty("IsShort", IsBlubb);
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DeclareProperty("IsShort", IsBlubb);
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This automatically defines
- an elementary filter HasIsShort,
Properties

A Property “XYZ” is realised by:

- an elementary filter HasXYZ and
- an elementary filter XYZ.

Properties are declared like this:

```
DeclareProperty("IsShort", IsBlubb);
```

This automatically defines

- an elementary filter HasIsShort,
- an elementary filter IsShort,
Properties

A Property “XYZ” is realised by:

- an elementary filter \texttt{HasXYZ} and
- an elementary filter \texttt{XYZ}.

Properties are declared like this:

\begin{verbatim}
DeclareProperty("IsShort", IsBlubb);
\end{verbatim}

This automatically defines

- an elementary filter \texttt{HasIsShort},
- an elementary filter \texttt{IsShort},
- an operation \texttt{IsShort},
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A Property “XYZ” is realised by:
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- an elementary filter \texttt{XYZ}.

Properties are declared like this:

\begin{verbatim}
DeclareProperty("IsShort", IsBlubb);
\end{verbatim}

This automatically defines
- an elementary filter \texttt{HasIsShort},
- an elementary filter \texttt{IsShort},
- an operation \texttt{IsShort},
- a method for \texttt{IsShort for objects in the filter IsBlubb and HasIsShort}, which just checks the type, and
Properties

A Property "XYZ" is realised by:
- an elementary filter HasXYZ and
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Properties are declared like this:
```
DeclareProperty("IsShort", IsBlubb);
```

This automatically defines
- an elementary filter HasIsShort,
- an elementary filter IsShort,
- an operation IsShort,
- a method for IsShort for objects in the filter IsBlubb and HasIsShort, which just checks the type, and
- an operation with method SetIsShort.
Attributes

```
DeclareAttribute("NrLetters", IsBlubb);
```
Attributes

```plaintext
DeclareAttribute("NrLetters", IsBlubb);
```

defines automatically

- an elementary filter `HasXYZ`,
Attributes

DeclareAttribute("NrLetters", IsBlubb);

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DeclareAttribute("NrLetters",IsBlubb);

defines automatically

- an elementary filter HasXYZ,
- an operation XYZ.

If one inherits from IsComponentObjectRep and IsAttributeStoringRep, then one also gets:

- An operation SetXYZ for [IsBlubb, IsObject] that stores the 2nd argument in the !.XYZ-component and sets HasXYZ.

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Attributes

\textbf{DeclareAttribute("	ext{NrLetters}", \text{IsBlubb});}

defines \textbf{automatically}

- an elementary filter \text{HasXYZ},
- an operation \text{XYZ}.

\textbf{If one inherits from} \text{IsComponentObjectRep and IsAttributeStoringRep, then one also gets:}

- An operation \text{SetXYZ} for \text{[IsBlubb, IsObject]} that stores the 2nd argument in the \text{!.XYZ}-component and sets \text{HasXYZ}.
- Every method for \text{XYZ} stores its result automatically in that component and sets \text{HasXYZ}. 
DeclareAttribute("NrLetters",IsBlubb);

defines **automatically**

- an elementary filter $\text{HasXYZ}$,
- an operation $\text{XYZ}$.

**If one inherits** from $\text{IsComponentObjectRep}$ and $\text{IsAttributeStoringRep}$, **then one also gets:**

- An operation $\text{SetXYZ}$ for $\text{[IsBlubb,IsObject]}$ that stores the 2nd argument in the $\text{!.XYZ}$-component and sets $\text{HasXYZ}$.
- Every method for $\text{XYZ}$ stores its result automatically in that component and sets $\text{HasXYZ}$.
- A very highly ranked method for $\text{XYZ}$ for objects in the filter $\text{IsBlubb}$ and $\text{HasXYZ}$ that simply returns $\text{!.XYZ}$.
In our example, we can simply replace

```gap
DeclareCategory("IsBlubb",
                IsComponentObjectRep);
DeclareOperation("IsShort", [IsBlubb]);
DeclareOperation("NrLetters", [IsBlubb]);
```

by

```gap
DeclareCategory("IsBlubb",
                IsAttributeStoringRep);
DeclareProperty("IsShort", IsBlubb);
DeclareAttribute("NrLetters", IsBlubb);
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and automatically get caching:
In our example, we can simply replace

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by

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DeclareCategory("IsBlubb",
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DeclareProperty("IsShort", IsBlubb);
DeclareAttribute("NrLetters", IsBlubb);
```

and automatically get caching:

```
gap> b := Blubb("abac",17);
<\texttt{a dense blubb wo=abac p=17}>
gap> HasNrLetters(b);
false
gap> NrLetters(b);

true
```
Debugging

If you want to see which methods are available:

```
gap> ApplicableMethod(NrLetters,[b],3,"all");
#I Searching Method for NrLetters with 1 arguments:
#I Total: 2 entries
#I Method 1: "NrLetters: system getter", value: 2*SUM_FLAGS+4
#I - 1st argument needs [ "IsAttributeStoringRep", "Tester(NrLetters)" ]
#I Method 2: "NrLetters: for dense Blubbs", value: 3
#I Skipped:
[ function( bl ) ... end ]
```
The complete example

BindGlobal("BlubbsFamily",
    NewFamily("BlubbsFamily"));
DeclareCategory("IsBlubb",
    IsAttributeStoringRep);
DeclareRepresentation("IsBlubbDenseRep",
    IsBlubb, ["wo", "p"]);
BindGlobal("BlubbDenseType",
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DeclareOperation("Blubb", [IsString, IsInt]);
DeclareProperty("IsShort", IsBlubb);
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end);
The complete example, continued

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   function(bl)
      return Length(bl!.wo) <= 5;
   end);

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InstallMethod(ViewObj,"for dense Blubbs",
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   end);