Compositional Model-Views with Generic Graphical User Interfaces

Peter Achten, Marko van Eekelen, and Rinus Plasmeijer
Department of Software Technology, University of Nijmegen, Toernooiveld 1, 6525 ED Nijmegen, The Netherlands
Telephone: +31 24 365 2644, Fax: +31 24 365 2525, peter88@cs.kun.nl, marko@cs.kun.nl, rinus@cs.kun.nl

Abstract. Creating GUI programs is hard even for prototyping purposes. Using the model-view paradigm makes it somewhat simpler since the model-view paradigm dictates that the model contains no GUI programming, as this is done by the views. Still, a lot of GUI programming is needed to implement the views.

We present a new method for constructing GUI applications that fits well in the model-view paradigm. Novel in our approach is that the views also contain no actual GUI programming. Instead, views are constructed in a fully compositional way by defining a model of the view. We use a technique developed earlier to generate the GUI part. We show how the method supports flexibility, compositionality and incremental change by introducing abstract components in the view models.

Keywords: Graphical User Interfaces, Generic and Functional Programming.

1 Introduction

The design of high quality user interfaces is an iterative process that has a great demand for rapid prototyping and flexible incremental change of versions of the UI under construction [13]. In practice, writing effective Graphical User Interfaces (GUI) with programming toolkits for even small programs (500 lines of code) is a complicated task. This is caused by two major obstacles:

A. The programmer needs to be skilled in the API of the used library and the tools that help him in his task (such as resource editors).

B. GUI programs tend to tie up the logic of the application with the realization of its user interface.

In this paper we show how contemporary functional language techniques using generic programming and strong type system features (existential types and rank-2 polymorphism) can be employed to obtain a programming toolkit that eliminates these obstacles. Even though the used techniques are advanced, the resulting API of this toolkit is concise, and the method-of-use is not hard, as will be demonstrated in this paper.

The system described in this paper fits well in the well-known model-view paradigm [12], introduced by Trygve Reenskaug in the language Smalltalk (the paradigm was then
named the model-view-controller paradigm). In our approach the data type plays the model role, and the views are derived automatically from the generic decomposition of values of that type. The controller role is dealt with by both the automatically derived communication infrastructure and the views (as they need to handle user actions).

In our method we will eliminate obstacle A by using Graphical Editor Components [3]. A GECt is an interactive editor (the view) to edit values of arbitrary data type t (the model) in a type-safe way. Using generic programming techniques, the view is automatically derived from the type t of the model. Hence, the programmer does not need to know about GUIs. One might gather that this is also sufficient to eliminate obstacle B, but this is not the case. The obstacle is still present in two ways:

B.1. The type of the model not only represents the data that is used by the application logic, but at the same time it represents the information that is needed to automatically generate the intended view. In this sense, the view is not well separated from the model.

B.2. A different editor can only be specified by defining a different type. Consequently, changing views incrementally implies changing types which in its turn implies further changes reducing flexibility.

In this paper, B.1 is dealt with by imposing a strict separation of concerns of the model. Instead of one model, the programmer defines a data model and a view model and their relation in the form of two conversion functions. Then, the GEC system can be used to derive the intended GUI from the view model. B.2 is dealt with by introducing abstract views (AGECs) that can be used as components of the view model. Due to the power of abstraction AGECs are fully compositional. The resulting system encourages an incremental methodology of programming GUIs. For rapid prototyping purposes, one starts with identical types for the data model and view model and the trivial identity transformation functions. Then, one can start to change views incrementally by changing instances of abstract component views in the view model.

The language that we have used is Clean, but it should be noted that the approach is applicable to other functional languages (with other I/O libraries) that support the above mentioned features as well, for instance Generic Haskell [9]. In principle, this can be done with any I/O library but using the Haskell Object I/O library [2,5] will minimize the effort of porting the system.

This paper is organized as follows. In Sect. 2 we recapitulate the concept of a GEC. Using these GECs as basic building blocks, we show in Sect. 3 how we eliminate obstacles B.1 and B.2, giving us the intended system. We present related work in Sect. 4 and conclude and point to future work in Sect. 5.

2 The Concept of a Graphical Editor Component

In [3] we introduced the concept of a Graphical Editor Component, a GECt. A GECt is an editor for values of type t. It is provided with an initial value of type t and it is guaranteed that an application user can only use the editor to create values of type t. At all times, a GECt contains a value of type t.

A GECt is generated with a generic function [10,4]. A generic function is a meta description on the structure of types. For any concrete type t, the compiler is able to automatically derive an instance function of this meta description for the given type.
Currently, we support all Clean types, with exception of function and abstract types.
The power of a generic scheme is that we obtain an editor for free for any data type.
This makes the approach particularly suited for rapid prototyping.

Before explaining GECs in more detail, we need to point out that Clean uses an
explicit environment passing style [1] for I/O programming. This style is supported by
the uniqueness type system [6] of Clean. Because GECs are integrated with Clean Object
I/O, the I/O functions that are presented in this paper are state transition functions
on the program state (PSt st). The program state represents the external world of
an interactive program, tailored for GUI operations. In this paper the identifier env is a
value of this type. In the Haskell variant of Object I/O, a state monad is used instead.
The uniqueness type system of Clean ensures single threaded use of the environment.
Uniqueness type attributes that actually appear in the type signatures are not shown
in this paper, in order to simplify the presentation.

2.1 Creating GECs

A GEC is a graphical editor component to edit values of type t. These editors are created
with the generic function gGEC. This function takes a definition (GECDef t env)
of a GEC, and creates the GEC object in the environment. It returns an interface
(GECInterface t env) to that GEC object. It is a (PSt ps) transition function because
gGEC modifies the environment.

\[
\text{generic gGEC } t :: \text{GECFunction } t ~ (\text{PSt st})
\]

A GEC is defined by GECDef t env which consists of two elements. The first is a
value of type t which will be the initial value of the editor. The second is a call-back
function of type \( t \to env \to env \). The editor must know what parts of the program are
interested in changes of the current value that are done by the user. This information
is provided by its 'context' in the form of this call-back function. The editor uses this
function when the user has changed the current value of the editor.

\[
\text{:: GECDef } t~\text{env} ~::~ (t, \text{CallBackFunction } t \to env \to env)
\]

The GECInterface t env is a record that contains all methods that the 'context'
can use to handle the newly created GEC.

\[
\text{:: GECInterface } t~\text{env} ~::~ \{ \text{gecGetValue} :: env \to (t,env),
\quad \text{gecSetValue} :: t \to env \to env \} \]

The method gecGetValue can be used to obtain the currently stored value of type
t from the GEC component. The method gecSetValue can be used to set a new value
in the corresponding GEC. GECInterface contains several other useful methods for a
program that are not shown above. These are methods to open and close the created
GEC and to show or hide its appearance.

The appearance of a standard GEC is illustrated by the following example. Assume
that the programmer has defined the type Tree a as shown below and consider the
following application of gGEC:
Tree a = Node (Tree a) a (Tree a) | Leaf

gGEC (Node Leaf 1 Leaf, const id) env

This creates a \( GEC_{\text{Tree Int}} \) which displays the indicated initial value (see Fig. 1). The application user can manipulate this value in any desired order thus producing new values of type Tree Int. Each time a new value is created, the call-back function is applied automatically. The call-back function of this first example (const id) has no effect. The shape and lay-out of the tree being displayed adjusts itself automatically. Default values are generated by the editor when needed.

Fig. 1. The initial Graphical Editor Component for a tree of integers (Left) and a changed one (Right: with the pull-down menu the upper Leaf is changed into a Node).

2.2 Self-adjusting Graphical Editor Components

In [3] a number of examples are given to show how graphical editor components can be combined relying on the call-back mechanism and method invocation. In this paper we only use one particular form of combination, namely that of an editor that itself reacts to edit operations by the user. In this way, an editor can be self-correcting: any property on edit values of type a that is expressable by means of a function \( f : : a \to a \) can be considered to be an invariant on the editor. As an example, we can construct a sorted-list editor by applying the sort function to all edited values.

Self-adjusting editors can be created with the concise function selfGEC:

\[
\text{selfGEC} : : (a \to a) \to (\text{PSt ps}) \to (\text{PSt ps}) | \text{gGEC(\text{a})}
\]

\[
\text{selfGEC } f \ va \ env = \text{new_env}
\]

where

\[
(\text{thisGEC,new_env}) = \text{gGEC} (f \ va, \lambda \text{nva}. \ \text{thisGEC.gecSetValue (f nva)}) \ \text{env}
\]

The function selfGEC, when applied to a function \( f : : a \to a \) and value \( va : : a \), creates a \( GEC_a \) with initial value \( f \ va \). The call-back function of this \( GEC_a \) is quite remarkable. At each change of value the editor re-applies \( f \) to the new value of type \( a \) and sets it as the actual new value of \( \text{itself} \). Notice that, due to the explicit environment passing style, it is trivial in Clean to connect \( GEC_a \) to itself. In Haskell’s monadic I/O one needs to tie the knot with fixIO.

2.3 Customizing Graphical Editor Components

The generic definition of gGEC enables the system to derive a \( GEC_t \) for arbitrary values of type \( t \). Occasionally one needs to deviate from the standard \( GEC_t \) because it does
not suit the requirements of the particular application. In [3] we show that this can be done by defining special instances for the types that need to be customized. This has been demonstrated for the ubiquitous `counter` example. In Fig. 2 the self-correcting code (updCntr) and model type (Counter) is given. The default GECcounter (shown at the bottom in Fig. 2) is a mirror image of the generic representation of the Counter model. It works as intended, and we get it for free. Unfortunately, its view is a counterexample of a good-looking counter.

```
 updCntr :: Counter -> Counter
 updCntr (n,Up) = (n+1,Neutral)
 updCntr (n,Down) = (n-1,Neutral)
 updCntr any = any

:: Counter := (Int,UpDown)
:: UpDown = Up | Down | Neutral
```

Fig. 2. Two GECCounter's created by selfGEC updCntr (0,Neutral). The standard one (bottom) and a customized one (top).

The changes that are required to obtain the customized editor are to define new generic instances for (,) (hide the constructor and place its arguments next to each other) and UpDown (display ±1 instead of Neutral).

Although in a slightly artificial way, this example demonstrates the obstacles B.1 and B.2 that we intend to remove. The increment/decrement behaviour that is captured with the UpDown type also fixes the derived GUI. The only ways to change the GUI are to use another type for this behaviour or to customize the editor for that type, as shown above.

3 Compositional Graphical Editor Components

Using the generic gGEC function, we automatically get an editor for any data type we invent. This is great for rapid prototyping. However, the appearance of the editor that we get for free in this way, might not resemble what we have in mind. We have explained in Sect. 2.3 that an editor can be customized for a specific type by defining a specialized instantiation of the generic function gGEC for that type. For certain basic types e.g. representing buttons and the like, this is exactly what we want. We also want to be able to create new editors from existing ones in a compositional way. Editors are automatically generated given a concrete type and a value of that type. The only way we can change this is by defining specialized editors for certain types. We need to invent a new way to realize abstraction and composition based on this specialization mechanism. In the following sections we show step by step how this can be accomplished.

First, we show in Sect. 3.1 how a program can be split such that a clear separation can be made between editor dependent and editor independent code. This makes it possible to choose any editor just by making changes to the editor dependent code, while we never have to make any changes to the editor independent code. Next, in Sect. 3.2 we show how to construct self-contained editors that take care of their own update
and conversion behaviour. Finally, in Sect. 3.3 we turn these self-contained editors into abstract reusable editors, thus encapsulating all information about their implementation and behaviour. However, abstract types seem to be at odds with generic programming. We show in Sect. 3.3 how we have managed to solve this problem.

Although the solution requires high-level functional and generic language constructs, it should be emphasized that editors remain very straightforward to use. In this section we construct a running example to illustrate the technique. The code fragment (1) below shows the data model. Code fragments appear as framed pieces of code. The data model is a record of type MyDataModel. The intention is that whenever the user edits one of the fields value1 or value2, then these new values are summed and displayed in field sum. This behaviour is defined by updDataModel. We want to emphasize that the types and code are ‘carved in stone’: they do not change in the rest of this paper.

\[
\text{MyDataModel} = \{ \text{value1 :: Int, value2 :: Int, sum :: Int} \}
\]

\[
\text{initDataModel} (v1,v2) = \{ \text{value1} = v1, \text{value2} = v2, \text{sum} = v1 + v2 \}
\]

\[
\text{updDataModel} :: \text{MyDataModel} \rightarrow \text{MyDataModel}
\]

\[
\text{updDataModel} \text{ rec} = \{ \text{ rec & sum = rec.value1 + rec.value2 } \}
\]

The ‘functional record update’ notation \{ \text{r & f o ... fn} = v0 ... vn \} creates a new record value in which all fields have the same value as in r except the updated fields \text{fo ... fn}.

3.1 Separation of Concerns by Separating Types

First of all, we want to accomplish a good separation of concerns. Ideally, it should be possible to concentrate on the functionality of the program without worrying about the actual shape of the editors. If one is not happy with the standard editor, it should be possible to construct the appropriate editor later without being forced to modify code that is not shape-related.

Using the function selfGEC we can immediately get a \text{GECMyDataModel} for free for testing purposes. Below we show what the \text{GECMyDataModel} GUI looks like when created by the function standardEditor. Each time the application user changes a value with the editor, the function updDataModel is applied and a new sum is calculated and displayed.

\[
\text{standardEditor} = \text{selfGEC updDataModel}
\]

\[
(\text{initDataModel} (0,0))
\]

Now suppose that we do not like the look of this standard editor very much, and want a different one. This is myEditor shown below in code fragment (2). Again, this code is ‘carved in stone’. We want to reuse the counters of the previous section for editing the two value fields. As the sum is calculated given these two values, we do not want the sum value to be editable at all.
myEditor to from
- selfGEC (to o updDataModel o from)
  (to (initDataModel (0,0)))

Since editors are created fully automatically just by looking at the type, the only way to obtain the desired editor is by using suited data types. For the counters we use the Counter type. We assume that we have a specialized basic editor for the type Display a: this editor shows any value of type a, but the value cannot be changed in the editor. We combine these types in a new type to obtain the desired editor.

As we said before, we do not want to change the code fragments (1) and (2). For this reason we make a clear distinction between the model of the data (MyDataModel) and the model of the view used to generate the editor we want (MyViewModel). Conversion functions between these two models need to be defined (toMyViewModel and fromMyViewModel).

This strict separation of concerns removes obstacle B.1: the data model has nothing to do with the means of visualization; this is done by the view model.

We can now easily express in the function myEditor how the view and model are connected. To glue them together we just need two conversion functions to and from the editor domain. We convert the initial value initDataModel to the view domain and create an editor. After a change being made with the editor we convert the new values back to the data model domain, apply the algorithm updDataModel, and convert the result back to the view domain such that it can be displayed and edited again.

Consequently, we obtain a running editor by applying:

myEditor toMyViewModel fromMyViewModel

The editor we get is completely determined by the type of MyViewModel and the definition of the conversion functions. If we want another editor, we only have to change this type and/or these conversion functions, all other code remains the same.

:: MyViewModel = { edvalue1 :: Counter // an updown counter, edvalue2 :: Counter // an updown counter, edsum :: Display Int } // non-editable integer value
toMyViewModel :: MyDataModel -> MyViewModel
toMyViewModel rec = { edvalue1 = toCounter rec.value1, edvalue2 = toCounter rec.value2, edsum = toDisplay rec.sum }

fromMyViewModel :: MyViewModel -> MyDataModel
fromMyViewModel edrec = { value1 = fromCounter (edrec.edvalue1), value2 = fromCounter (edrec.edvalue2), sum = fromDisplay edrec.edsum }

toCounter n = (n,Neutral)
fromCounter (n,_) = n

:: Display a = Display a
toDisplay \( x \) = Display \( x \)

fromDisplay (Display \( x \)) = \( x \)

In this way we have created a separate layer on top of the unchanged existing program. Unfortunately, we did not really reach the desired compositional behaviour. By choosing another data type one does obtain another editor for free that looks the way we want, but one does not automatically get the desired self-contained behaviour with it. For instance, we have used the type Counter in the definition of MyViewModel. The generated editor displays a counter, but it does not take care of the updates of the counter. This is clearly not what we want. We have to invent a type from which self-contained editors can be generated.

### 3.2 Defining Self-Contained Editors

If we want to reuse an existing editor, it is not enough to reuse its type. We also want to reuse its functionality: each editor should take care of its own update. For this purpose we need a type in which we can store the functionality of an editor. If want to create a view \( v \) on a domain model \( d \), we need to be able to replace a standard editor for type \( d \) by a self-contained editor for some isomorphic type \( v \). Furthermore, since we generally also have to perform conversions between these types, we like to store them as well, such that each editor can take care of its own conversions. Finally, it is generally useful to take into account the old value of \( v \) when converting from \( d \) since editors may have an internal state.

Therefore we define a new type, ViewGEC \( d,v \), in which we can store the update and conversion functions, and we define a specialized version of our generic editor gGEC for this type (gGEC([ViewGEC])). The definitions are given below. Notice that in gGEC([ViewGEC]) two additional parameters appear: gGEC\( d \) and gGEC\( v \). This is caused by the fact that generic functions in Clean are kind-indexed functions. As ViewGEC \( d,v \) is of kind \( * \to * \to * \), the generic function has two additional parameters, one for type \( d \) and one for type \( v \).

The ViewGEC editor does the following. The value of type \( d \) is stored in the ViewGEC record, but a \( d \)-editor (gGEC\( d \)) for it is not created. Taking the old value of \( v \) into account, the \( d \)-value is converted to a \( v \)-value using the conversion function \( d\text{oldv_to_v} :: d \to (\text{Maybe } v) \to v \). For this \( v \)-value we do generate a generic \( v \)-editor (gGEC\( v \)) to store and edit the \( v \)-value.

Whenever the application user creates a new \( v \)-value with this editor, the call-back function of the \( v \)-editor is called (viewCallback) and the \( \text{update}_v :: v \to v \) function is applied. This is similar to applying selfGEC \( \text{update}_v \) to the corresponding new value of type \( v \). The resulting new \( v \)-value is shown in the \( v \)-editor again, and it is converted back to an \( d \)-value as well, using the function \( \text{v_to_d} :: v \to d \). This new \( d \)-value is then stored in the ViewGEC record in the \( d\text{val} \) field, and the call-back function for the ViewGEC editor is called (viewGECcallback). The new \( d \)-value can be inspected in the program as if a new \( d \)-value was created with a standard generic \( d \)-editor.

\[
\text{:: ViewGEC } d\ v \ = \ \{ d\text{val} :: d \ ,
\text{d_oldv_to_v} :: d \to (\text{Maybe } v) \to v \ ,
\text{update}_v :: v \to v \ ,
\text{v_to_d} :: v \to d \} \]
mkViewGEC :: d (d → v) (v → v) (v → d) → ViewGEC d v
mkViewGEC d fdv fvv fvd = { d_val = d,
  d_oldv_to_v = fdv,
  update_v = fvv,
  v_to_d = fvd }

where
  fdvv d Nothing = fdv d
  fdvv _ (Just v) = v

gGECEntry gaysv w geCfd v gECd gECv = viewGECCallback new_env
  = ({{ gecSetValue = viewSetVal viewInterface
            , gecGetValue = viewGetVal viewInterface }},new_env)

where
  (vInterface,new_env) = gECv (viewGEC.d_oldv_to_v v viewGEC.d_val Nothing
            ,viewCallback vInterface
            ) env

viewCallback vInterface new_v env
  = viewGECCallback (viewGEC & d_val = new_d) new_env

where
  new_upd_v = viewGEC.update_v new_v
  new_env = vInterface.gecSetValue new_upd_v env
  new_d = viewGEC.v_to_d new_upd_v

viewSetVal vInterface new_viewGEC env
  = vInterface.gecSetValue new_v new_env

where
  newb = new_viewGEC.d_oldv_to_v new_viewGEC.d_val (Just old_v)
  (old_v,new_env) = vInterface.gecGetValue env

viewGetVal vInterface env
  = ({{viewGEC & d_val = viewGEC.v_to_d current_v},new_env)

where
  (current_v,new_env) = vInterface.gecGetValue env

The concrete behaviour of the generated ViewGEC editor now not only depends on
the type, but also on the concrete information stored in a value of type ViewGEC. Now
it becomes very easy to define self-contained reusable editors, such as a counter editor,
shown below. The corresponding editor takes care of the conversions and the update.
The displayGEC does a trivial update (identity) and also takes care of the required
conversions.

counterGEC :: Int → ViewGEC Int Counter
counterGEC i = mkViewGEC i toCounter updCntr fromCntr

displayGEC :: a → ViewGEC a (Display a)
displayGEC x = mkViewGEC x toDisplay id fromDisplay
Making use of these new self-contained editors we can repair and even simplify our previous editor definition. To replace it, we only have to provide a new definition of MyViewModel and of the conversion functions toMyViewModel and fromMyViewModel. All other definitions remain the same.

:: MyViewModel = { edvalue1 :: ViewGEC Int Counter
, edvalue2 :: ViewGEC Int Counter
, edsum :: ViewGEC Int (Display Int) }

toMyViewModel :: MyDataModel -> MyViewModel
toMyViewModel rec = { edvalue1 = counterGEC rec.value1
, edvalue2 = counterGEC rec.value2
, edsum = displayGEC rec.sum }

fromMyViewModel :: MyViewModel -> MyDataModel
fromMyViewModel edrec = { value1 = edrec.edvalue1.d_val
, value2 = edrec.edvalue2.d_val
, sum = edrec.edsum.d_val }

In the definition of toMyViewModel we can now simply choose any suited self-contained editor. Each editor handles the needed conversions and updates itself automatically. To obtain the value we are interested in, we just have to address the d_val field.

The example shows that we have obtained the compositional behaviour that we wanted to have. One problem remains. If we would replace a self-contained editor by another in toMyViewModel, all other code remains the same. However, we do have to change the type of MyViewModel. In this type it is completely visible what kind of editor has been used. The abstraction would be complete if we also manage to create an abstract data type for our self-contained editors.

3.3 Abstract Self-Contained Editors

The concrete value of type ViewGEC d v is used by the generic mechanism to generate the desired self-contained editors. The ViewGEC d v type depends on the type of the editor v that is being used. Put in other words, the type still reveals information about the implementation of editor v. This is undesirable for two reasons: one can not exchange views without changing types, and the type of composite views reflects their composite structure. For these reasons, we want a type that abstracts from the concrete editor type v.

However, if we manage to hide these types, how can the generic mechanism generate the editor for it? The compiler can only generate an editor for a given concrete type, not for an abstract type of which the content is unknown. The solution is as follows. When the abstraction is being made, we do know the contents and its type. Hence, we can store the generic editor function (of type GECFunction, see Sect.2.1) in the abstract data structure itself where the abstraction is being made. The stored editor function can be applied later when we really need to construct the editor. Therefore, we define an abstract data structure (AGEC d) in which we store the ViewGEC d v and its corresponding generic gGEC function for v. Technically this requires a type system that supports existentially quantified types as well as rank-2 polymorphism.
\[
:\text{AGEC} \ d = \exists \, \text{v} : \text{AGEC} \{\text{ViewGEC} \ d \ \text{v}\}
\]
(\forall \, \text{ps} : \text{GECFunction} \{\text{ViewGEC} \ d \ \text{v}\} \ (\text{PSt} \ \text{ps}))

\text{mkAGEC} :: \ (\text{ViewGEC} \ d \ \text{v}) \rightarrow \text{AGEC} \ d \ \mid \ \text{gGEC}\{[*]\} \ \text{v}
\text{mkAGEC} \ \text{viewGEC} = \text{AGEC} \ \text{viewGEC} \ (\text{gGEC}\{[* \rightarrow * \rightarrow *]\} \ \text{undef} \ \text{gGEC}\{[*]\})

\text{gGEC}\{\text{AGEC}\} = \ldots \ // \text{similar to} \ \text{gGEC}\{\text{ViewGEC}\}, \text{but apply function stored in AGEC}

The function \text{mkAGEC} creates the desired \text{AGEC} given a \text{viewGEC}. Looking at the type of \text{AGEC}, the generic system can deduce that the editor to store has to be a generic editor for type \text{ViewGEC} \ d \ \text{v}. To generate this editor, the generic system by default requires an editor for type \text{d} and type \text{v} as well. We know that in this particular case we do not use the \text{d}-editor at all. We can tell this to the generic system by making use of the fact that generic functions in \text{Clean} are kind indexed. The system allows us, if we wish, to explicitly specify the editors for type \text{d} (\text{undef}) and type \text{v} (\text{gGEC}\{[*]\}) to be used by the editor for \text{ViewGEC} (\text{gGEC}\{[* \rightarrow * \rightarrow *]\}). In this case we know that we do not need an editor for type \text{d} (hence the \text{undef}), and use the standard generic editor for type \text{v}. The overloading context restriction in the type of \text{mkAGEC} (\text{[gGEC}\{[*]\} \ \text{v}) states that for making an \text{AGEC} \ d out of a \text{ViewGEC} \ d \ \text{v} only an editor for type \text{v} is required.

We also have to define a specialized version of \text{gGEC} for the \text{AGEC} type. The corresponding generated editor applies the stored editor to the stored \text{ViewGEC}. The types and kind indexed generic programming features we have used here may look complicated, but for the programmer an abstract editor is easy to make. To use a self-contained editor of type \text{v} as editor for type \text{d}, a \text{ViewGEC} \ d \ \text{v} has to be defined. Note that the editor for type \text{v} is automatically derived for the programmer by the generic system! The function \text{mkAGEC} stores them both into an \text{AGEC}. The functions \text{counterAGEC} and \text{displayAGEC} show how easy \text{AGEC}'s can be made. One might be surprised that the overloading context for \text{displayAGEC} still requires a \text{d}-editor (\text{[gGEC}\{[*]\} \ \text{d}). This is caused by the fact that in this particular case type \text{d} is used in the definition of type \text{Display}.

\text{counterAGEC} :: \text{Int} \ \rightarrow \ \text{AGEC} \ \text{Int}
\text{counterAGEC} \ i = \text{mkAGEC} \ (\text{counterGEC} \ i)

\text{displayAGEC} :: \text{d} \ \rightarrow \ \text{AGEC} \ \text{d} \ \mid \ \text{gGEC}\{[*]\} \ \text{d}
\text{displayAGEC} \ x = \text{mkAGEC} \ (\text{displayGEC} \ x)

We choose to export \text{AGEC} \ d as a \text{Clean} abstract data type. This implies that code that uses such an abstract value can not apply record selection to access the \text{d} value. For this purpose we provide the following obvious projection functions to retrieve the \text{d}-value from an \text{AGEC} \ d (\text{"\textbf{\textendash}\textbf{\textendash}}} \) and to store a new \text{d} value in an existing \text{AGEC} \ d (the infix operator \text{\textbf{\textendash}\textbf{\textendash}}).

\text{\textbf{\textendash}\textbf{\textendash}}} :: \ (\text{AGEC} \ d) \ \rightarrow \ d \ // \text{Read current value}
\text{\textbf{\textendash}\textbf{\textendash}}} \ (\text{AGEC} \ \text{viewGEC} \ \text{gGEC}) = \text{viewGEC}.\text{d_val}

\text{\textbf{\textendash}\textbf{\textendash}}} \ \text{infixl} :: \ (\text{AGEC} \ d) \ \text{d} \ \rightarrow \ (\text{AGEC} \ d) \ // \text{Set new value}
\text{\textbf{\textendash}\textbf{\textendash}}} \ (\text{AGEC} \ \text{viewGEC} \ \text{gGEC}) \ n\text{val} = \text{AGEC} \ (\text{viewGEC} \ & \ \text{d_val} = \text{val}) \ \text{gGEC}
The inclusion of the abstract type $AGEC\ d$ together with its instance of $gGEC$, and the access functions provides the additional strength to the toolkit that is needed to successfully eliminate obstacle $B.2$.

We can now refine the three definitions of our running example for the last time and ‘carve it in stone’ as well in code fragment (4). All other code fragments remain unchanged. The complete code is formed by the code fragments (1)...(4) (with a few auxiliary functions).

```
:: MyViewModel = { edvalue1 :: AGEC Int
    , edvalue2 :: AGEC Int
    , edsum :: AGEC Int }

toMyViewModel :: MyDataModel
^ MyViewModel

toMyViewModel rec = { edvalue1 = counterAGEC
    , edvalue2 = counterAGEC
    , edsum = displayAGEC }

fromMyViewModel :: MyViewModel
^ MyDataModel

fromMyViewModel edrec = { value1 = ** edrec.edvalue1
    , value2 = ** edrec.edvalue2
    , sum = ** edrec.edsum }
```

The advantage we have obtained now is that, if we want to pick another editor, we only have to tell which one to pick in the definition of $toMyViewModel$. The types used in $MyViewModel$ all remain the same ($AGEC\ Int$), no matter which editor is chosen. Also the definition of $fromMyViewModel$ remains unaffected. It is instructive to compare the final definition with the one at the end of Sect. 3.2.

### 3.4 Abstract Editors Are Compositional

In order to show the compositional nature of abstract editors, we first turn the running example into an abstract editor, say $sumAGEC$, of type $AGEC\ Int$. In disguise, it can be used itself as an $Int$-editor. Following the scheme introduced above, this is done as follows:

```
sumAGEC :: Int \rightarrow AGEC Int
\hspace{1cm} // see counterAGEC (3.3)

sumAGEC i = mkAGEC (sumGEC i)

where

    sumGEC :: Int \rightarrow ViewGEC Int MyViewModel
\hspace{1cm} // see counterGEC (3.2)

    sumGEC i = mkViewGEC i to upd from

    where to = toMyViewModel o toMyData

    from = fromMyData o fromMyViewModel

    upd = toMyViewModel o updDataModel o fromMyViewData

    toMyData i = initData (0,i)

    fromMyData d = d.sum
```

Now $sumAGEC$, $counterAGEC$, and $displayAGEC$ are interchangeable components. If we want to experiment with variants of the running example, we simply pick the instance of our choice in the $toMyViewModel$ function. This is displayed in Fig. 3.
Alternative definition of toMyViewModel:

toMyViewModel1 rec
= { edvalue1 = idAGEC rec.value1
    , edvalue2 = idAGEC rec.value2
    , edsum = idAGEC rec.sum }

toMyViewModel2 rec
= { edvalue1 = idAGEC rec.value1
    , edvalue2 = counterAGEC rec.value2
    , edsum = displayAGEC rec.sum }

toMyViewModel3 rec
= { edvalue1 = counterAGEC rec.value1
    , edvalue2 = sumAGEC rec.value2
    , edsum = displayAGEC rec.sum }

Fig. 3. Plug-and-play your favourite abstract editors to experiment with the running example. The only code that changes is the function toMyViewModel.

We are setting up a library of abstract components. One of these library functions idAGEC (which takes a value of any type and promotes it to an abstract editor component for that type) is used in the example above. With this library it will be possible to rapidly create GUIs in a declarative style. This can be very useful e.g. for prototyping, education, tracing and debugging purposes.

4 Related Work

Our model-view approach has several interesting features that are not present in the standard approach [12]. Firstly, because views are derived automatically, a programmer in our system does not need to explicitly 'register' nor program views. Secondly, views can be customized via overruling instance declarations of arbitrary types. Finally, the most distinguishing feature of our model-view approach is the nature of both the model and the views. The generic framework dissects the offered type of the model into the set of generic types, each of which is mapped to an interactive model-view unit. Put in other words, our approach can truly be called model-view all the way.

Frameworks for the model-view paradigm in a functional language use a similar value-based approach (Claessen et al.[8]), or an event-based version [11]. In both cases, the programmer needs to explicitly handle view registration and manipulation. In our framework, the information-flow follows the structure that is derived by the generic decomposition of the model value. This suggests that we could have based our abstract GUI definitions on a stream-based solution such as FUDGETS [7]. However, stream based approaches are known to impose a much too rigid coupling between the stream based communication and the GUI structure resulting in a severe loss of flexibility.
and maintainability. For this reason, we have chosen to use a system with a call-back mechanism as the interface of its GUI components.

A project that also employs generic programming techniques to produce views is the Proxima PhD-project of Martijn Schrage at the University of Utrecht [14]. It is specifically geared towards the design and development of a generic presentation-oriented XML-editor.

Wolfram Kahl has developed a first version of editor combinators [15]. With editor combinators text-based structure editors can be defined and composed in a way which is similar to parser combinators.

To our knowledge there is no other declarative work for describing general purpose GUIs that achieves a similar abstraction level with such a complete separation of model and view.

5 Conclusions and Future Work

In this paper we have introduced a technique for programming GUIs that has the following properties:

- The programmer can separate application logic from view logic by defining a separate data model and view model.
- Using abstract GECs (in which a complete model-view is encapsulated) the programmer can incrementally change the view model without modifying its type.
- The programmer can use a library of abstract GECs to construct GUIs by composition without knowing anything about standard GUI libraries.
- The ease of programming with abstract GECs makes it very suited for use in education, tracing, debugging and rapid prototyping.

The Clean language that we have used in this project is a functional language with strong support for types, including existential types and rank-2 polymorphism. We rely essentially on generic programming with kind indexed types. The GUI part is implemented on top of the Object I/O library of Clean. The system could also have been realized in Generic Haskell using the Haskell Object I/O library.

Currently, function types are excluded from the system. We plan to include them in the near future. Furthermore, we will investigate the expressive power of our graphical editor components by setting up a library for abstract GECs and by performing case studies.

Acknowledgements

The authors would like to thank Pieter Koopman and Arjen van Weelden for their valuable comments on versions of this paper.

References


A Appendix

In three figures this appendix gives an overview of the three different methods for Model-View programming presented in the paper.

Fig. 4. Standard Model-View programming with GECs.

Fig. 5. Model-View programming with separated data model and view model.

Fig. 6. Model-View programming with in AGECs encapsulated data-view models.