GDC | **March 21-25, 2022**
San Francisco, CA

Immutable data for editor for EVE Echoes

#GDC22

THE
SCOPE

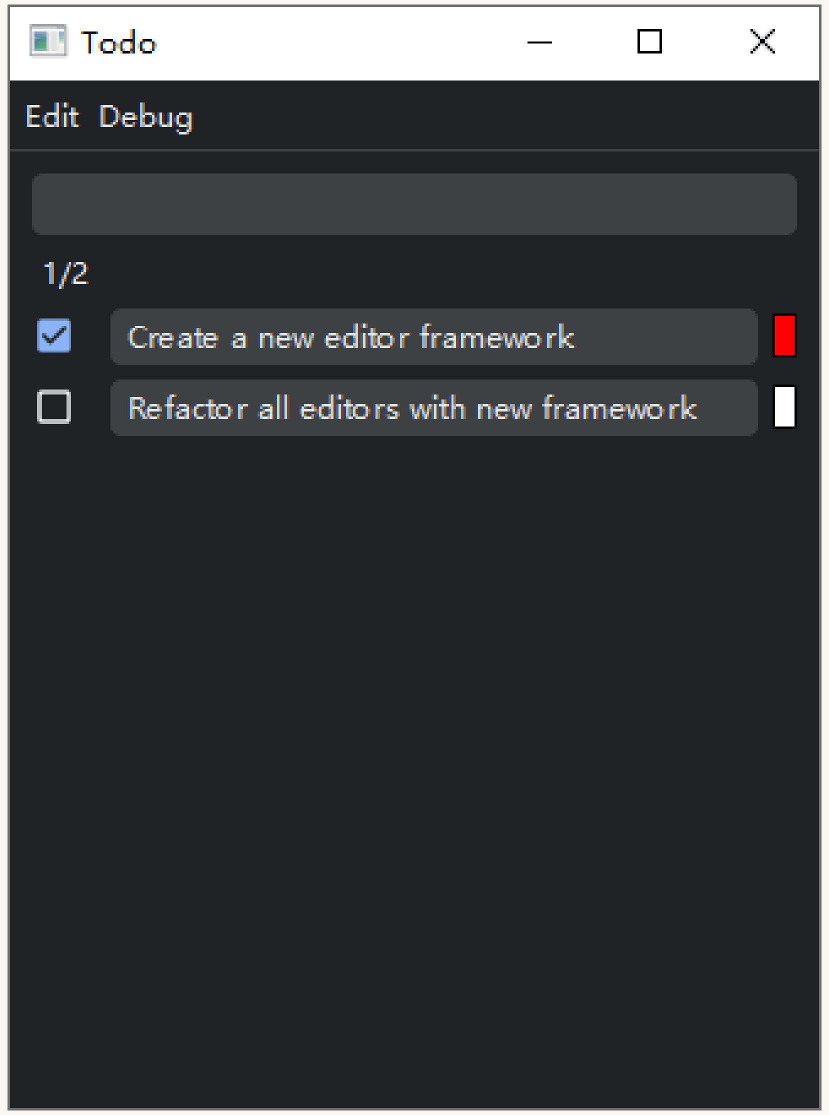
PREVIOUS WORK

Tools for 'Marvel's Spider-Man': Editing with Immutable Data
- Ron Pieket, GDC 2019

AGENDA

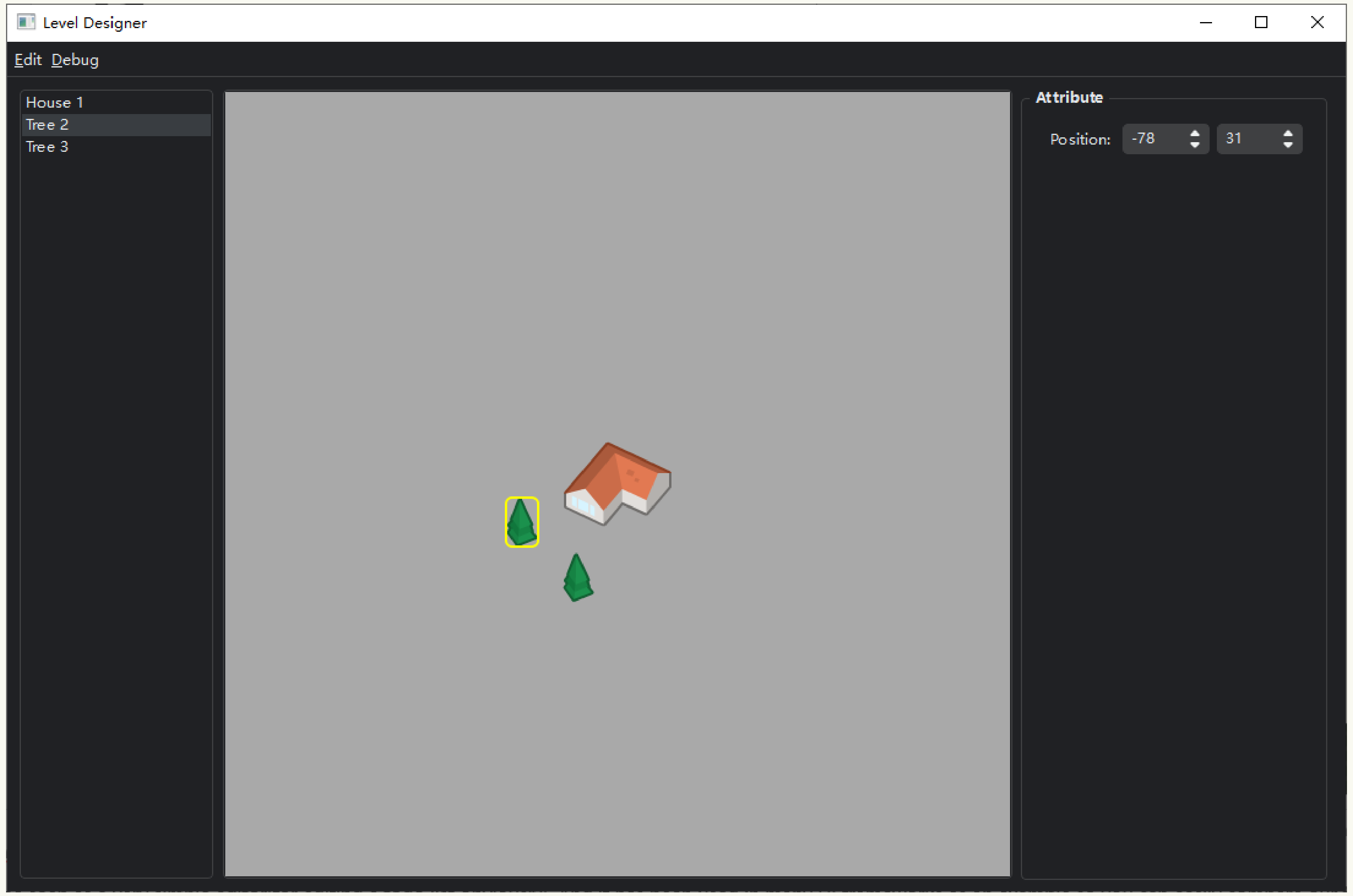
- Problems with event based editor
- How immutable data based editors work
- Automated testing
- Manage immutable data efficiently
- How is immutable data implemented

DEMO



1/2

- [x] Create a new editor framework 🟥
- [ ] Refactor all editors with new framework ⬜



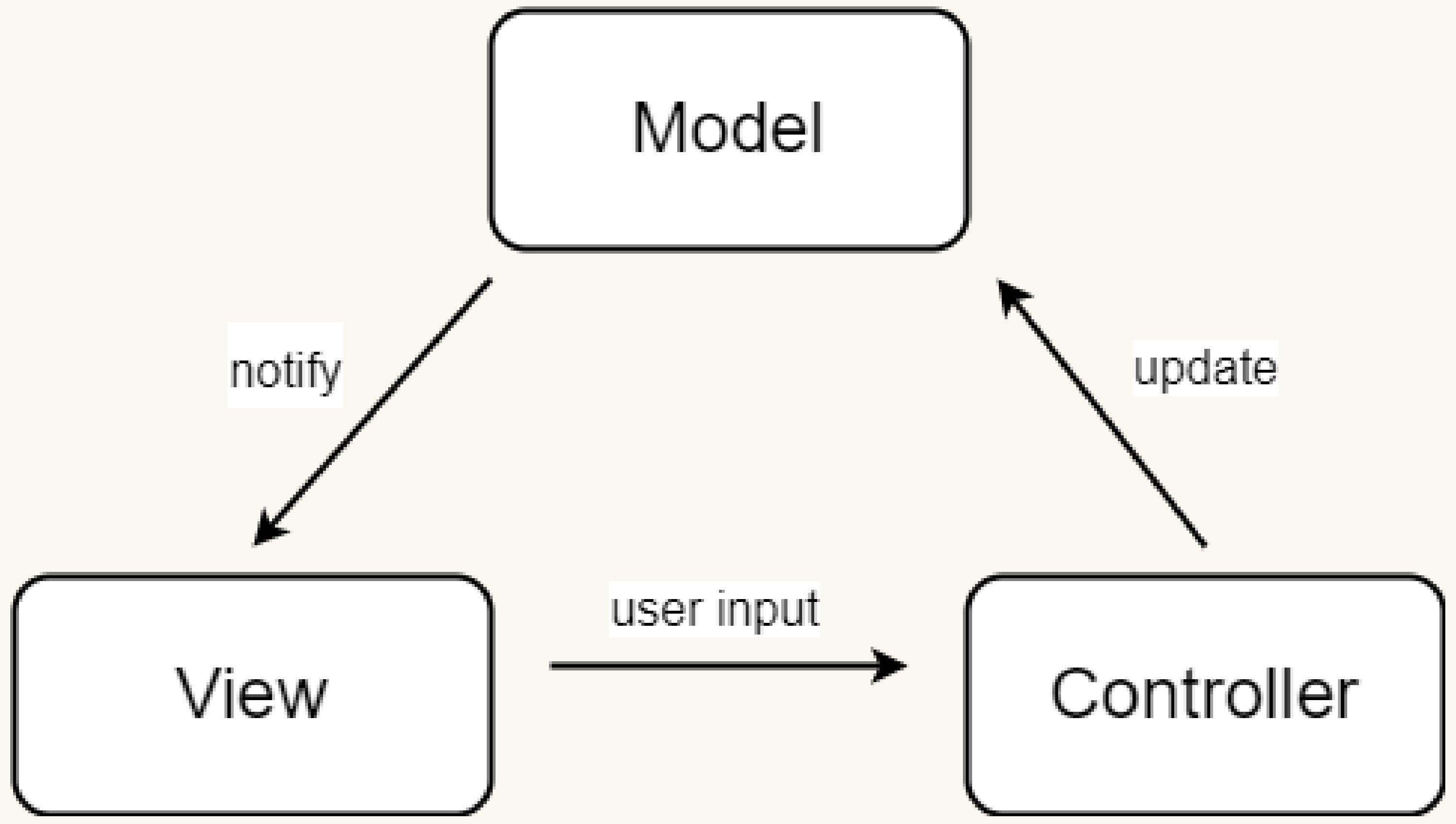
Position: -78 31

https://github.com/kkpattern/immu_editor_gdc

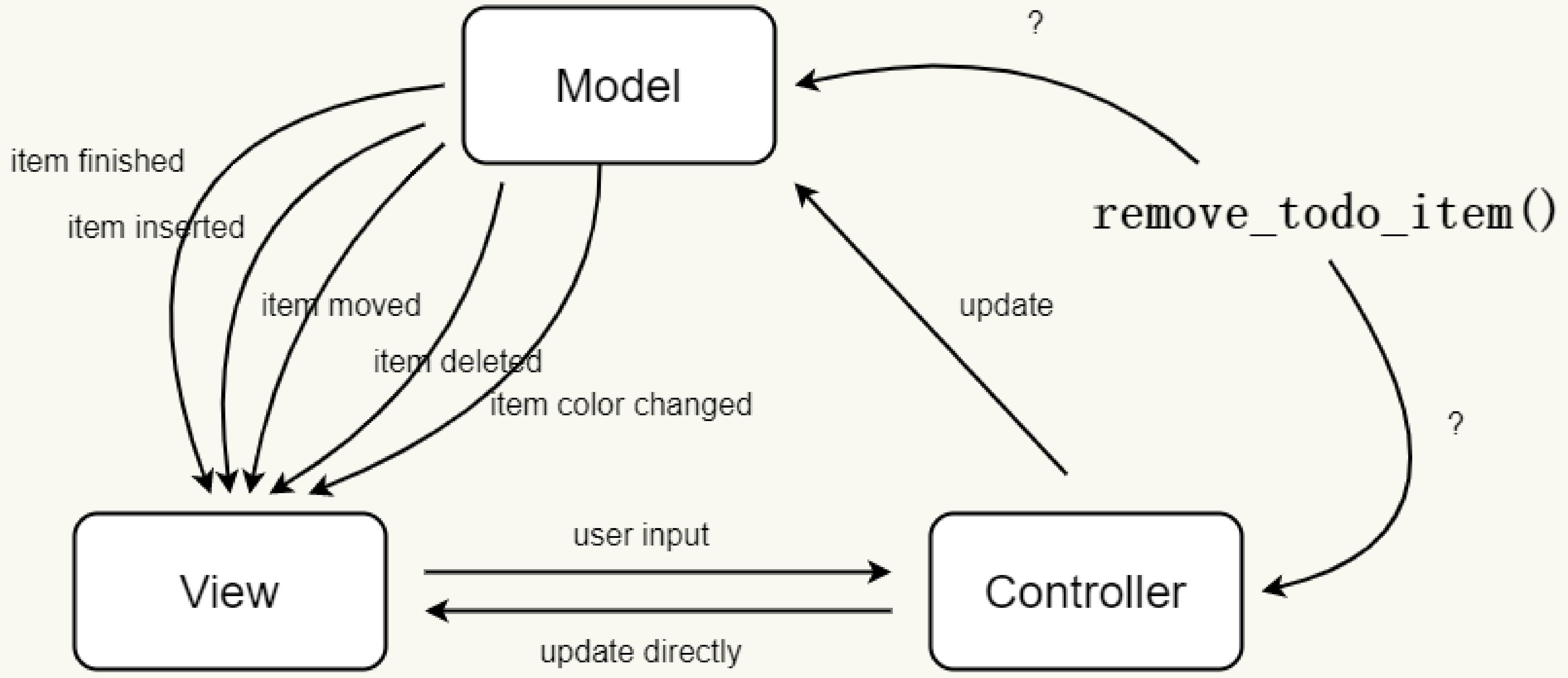
BACKGROUND

- Relatively small team
  - One dedicated tools developer
  - No dedicated tools QA
- New feature development always in a rush
- Unstable editors
- Editors no longer maintained

MVC



MVC


Model
?
item finished
item inserted
remove_todo_item()
item moved
update
item deleted
item color changed
?
user input
View
Controller
update directly

DIFF BASED UPDATE

- Hard to see the complete data
- Hard to detect and recover from out-of-sync

THE UNDO/REDO PROBLEM

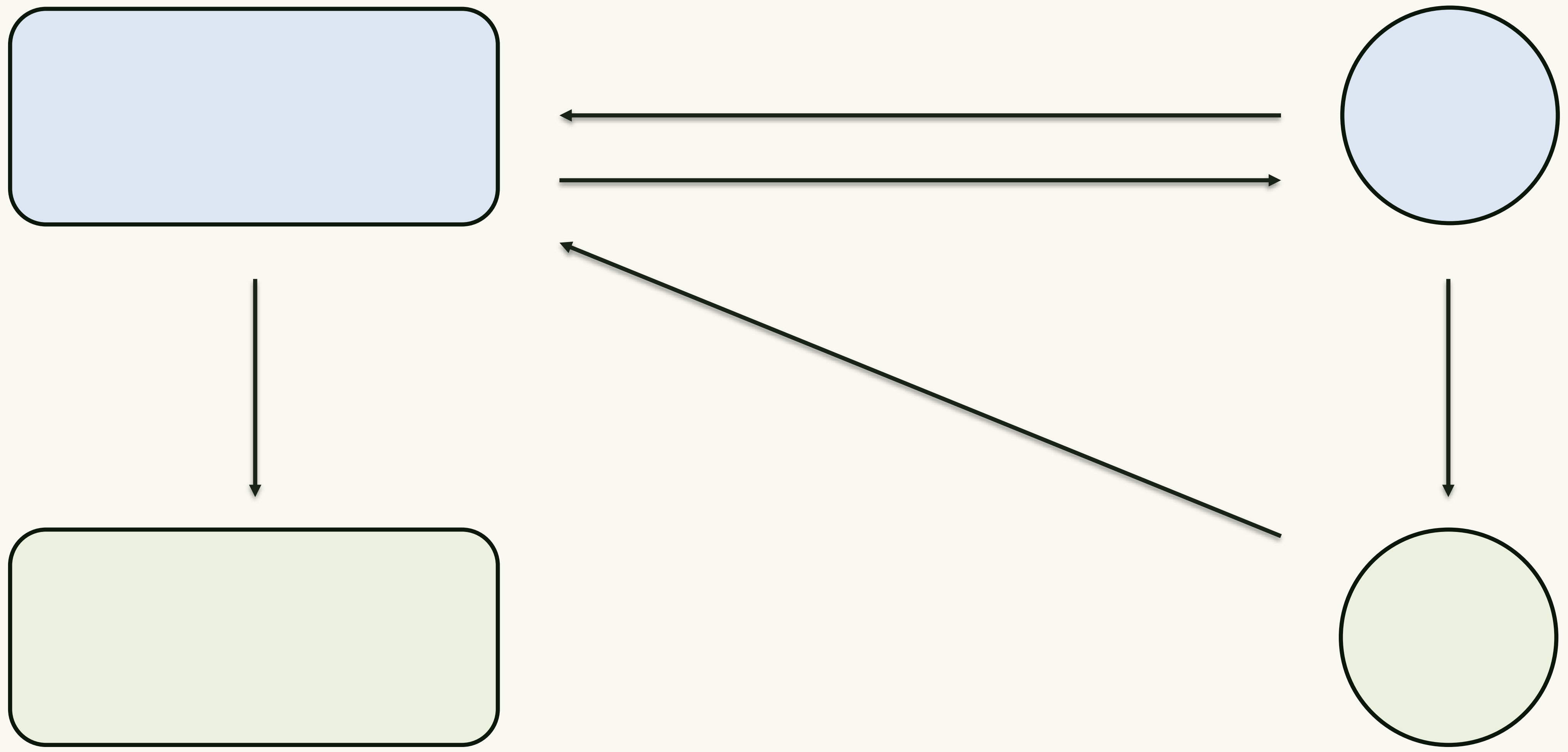
- Iteration is king
- Command pattern
- Undo/redo often non-trivial
- Developers tend not to provide new features

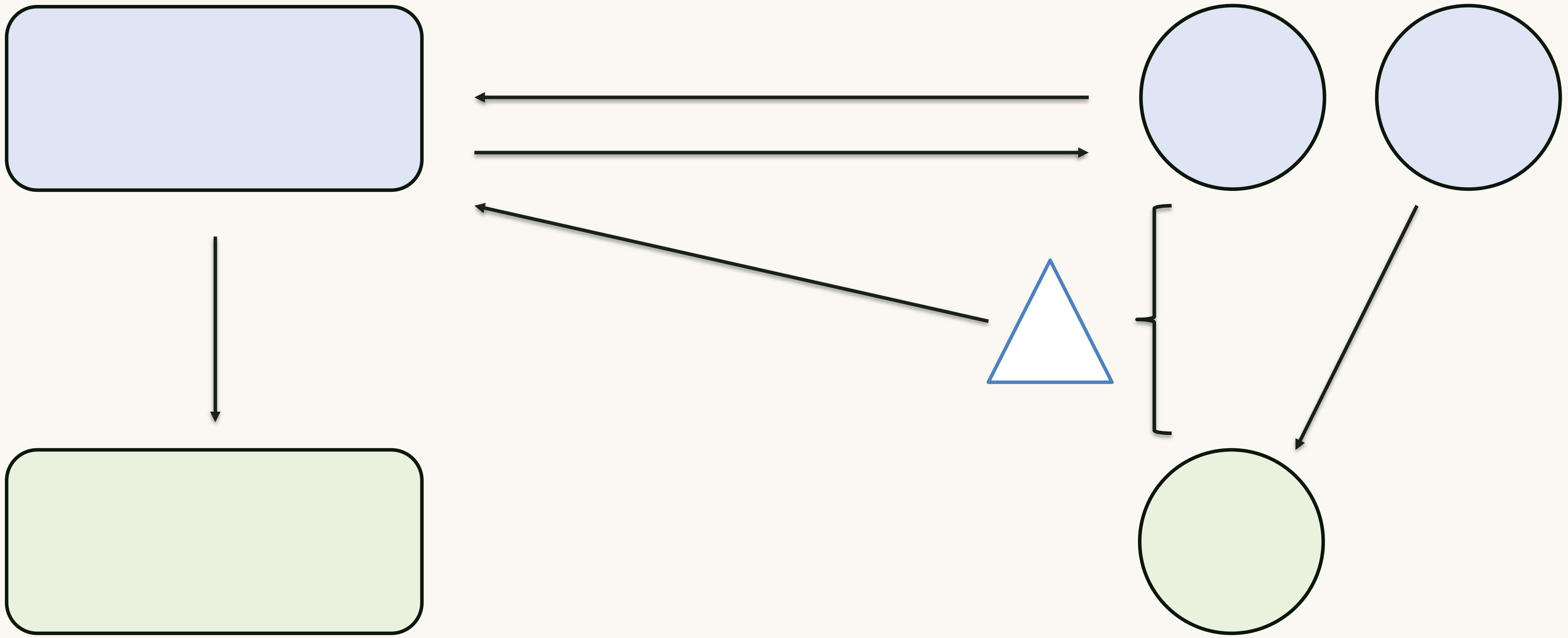
GOAL

- Increase editor stability
- Increase editor development efficiency
  - Provide a simple undo/redo solution
- Paradigm for all editors
- Fast (enough) performance

OTHER SOLUTIONS

- Declarative UI
- Immediate Mode UI





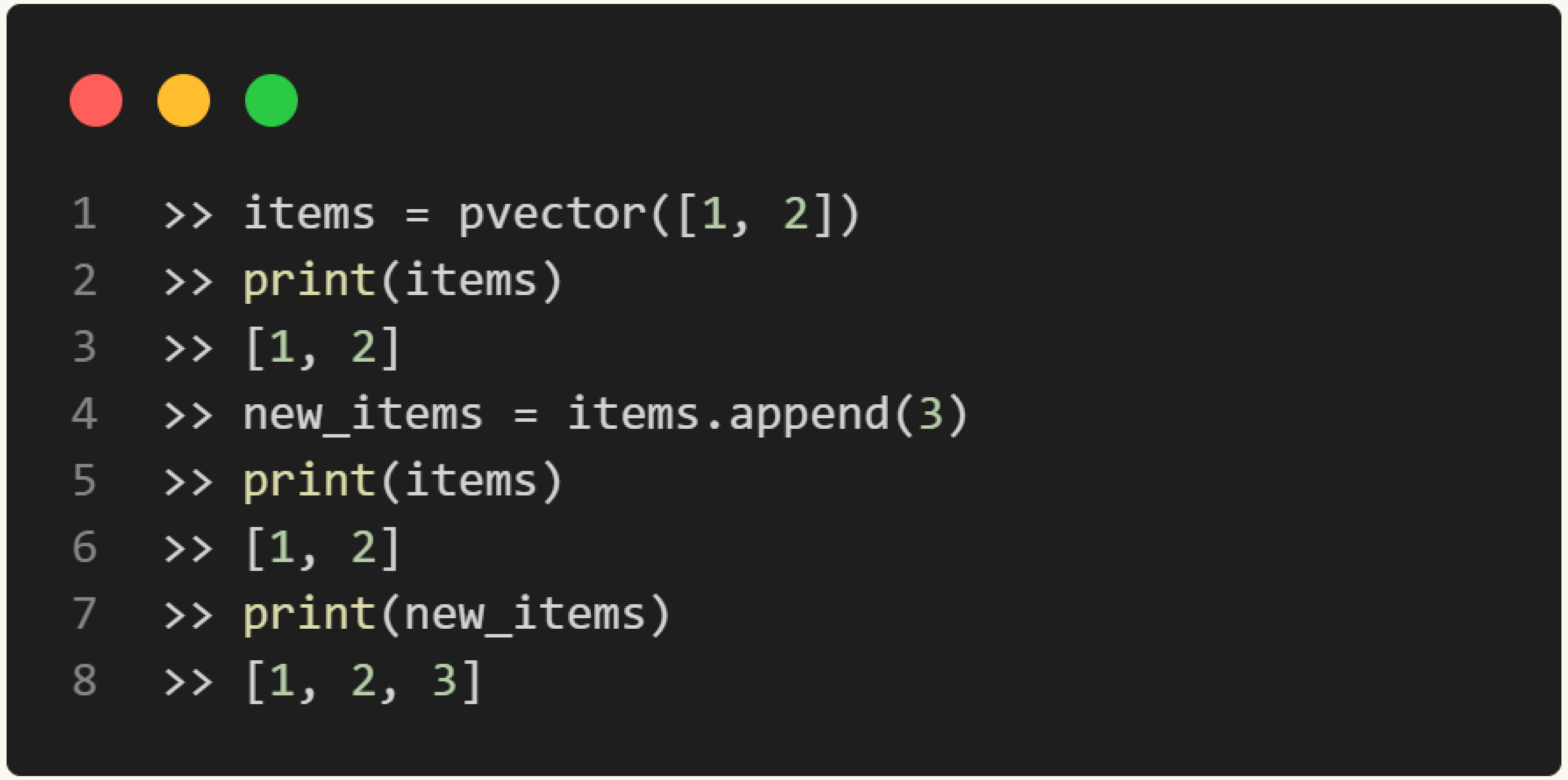
- Get the complete data
- Easier to detect and recover from out-of-sync
- Free undo/redo

- Copy can be expensive
- Copy can be hard
- Diff can be expensive
- Diff can be hard

IMMUTABLE DATA STRUCTURE

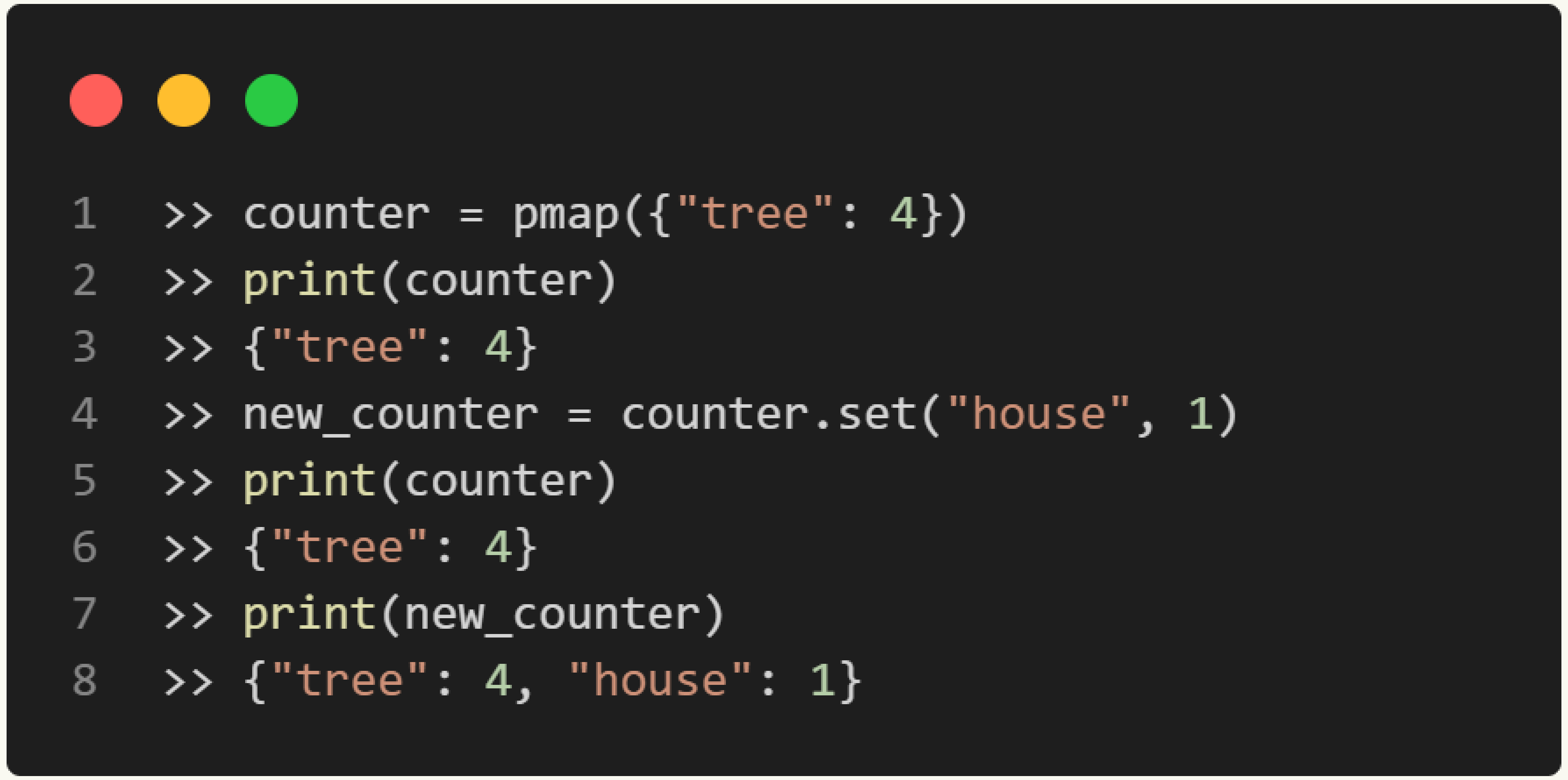
- Persistent data structure
- Cannot be changed
- Copy to modify

EXAMPLE: PYRSISTENT



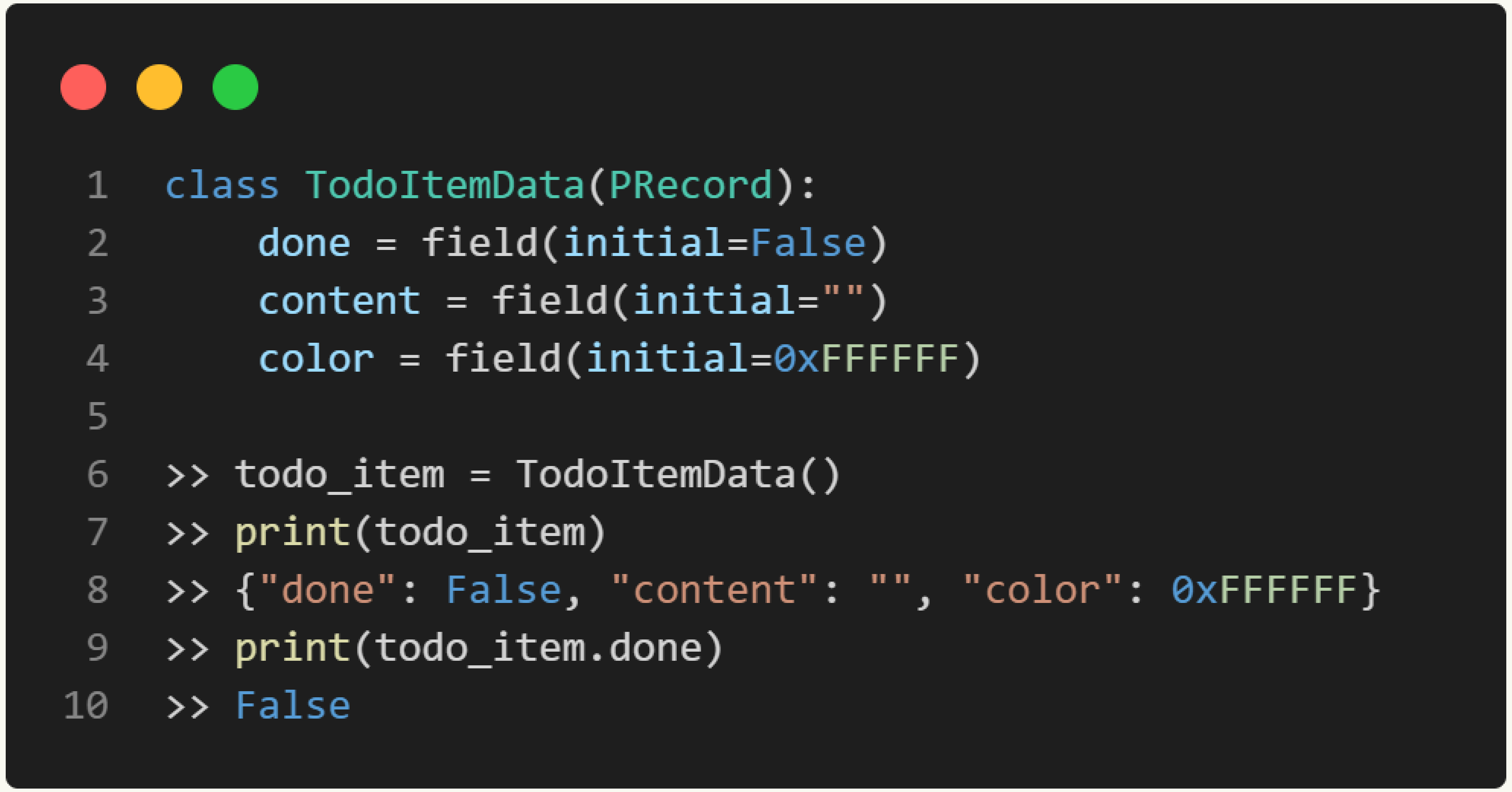
```
>> items = pvector([1, 2])
>> print(items)
>> [1, 2]
>> new_items = items.append(3)
>> print(items)
>> [1, 2]
>> print(new_items)
>> [1, 2, 3]
```

EXAMPLE: PYRSISTENT



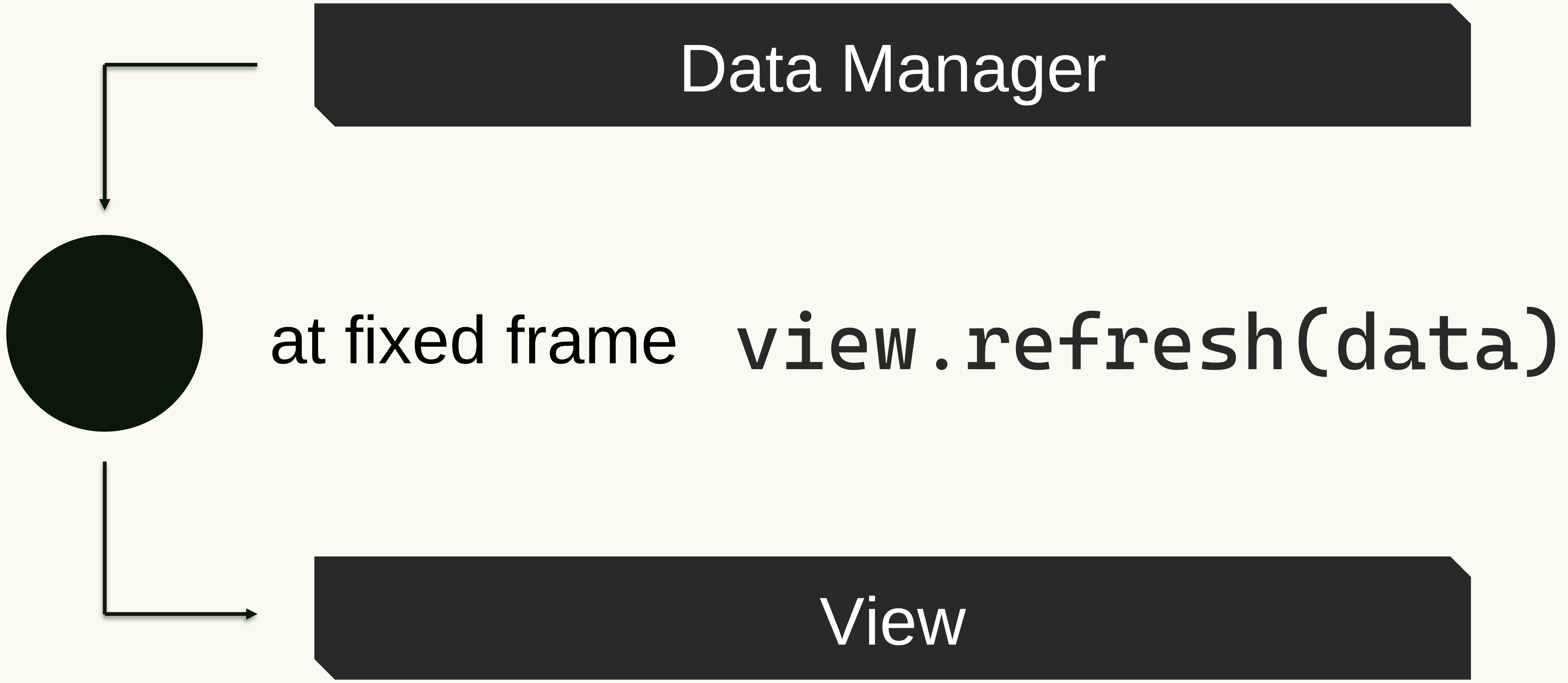
```
>> counter = pmap({"tree": 4})
>> print(counter)
>> {"tree": 4}
>> new_counter = counter.set("house", 1)
>> print(counter)
>> {"tree": 4}
>> print(new_counter)
>> {"tree": 4, "house": 1}
```

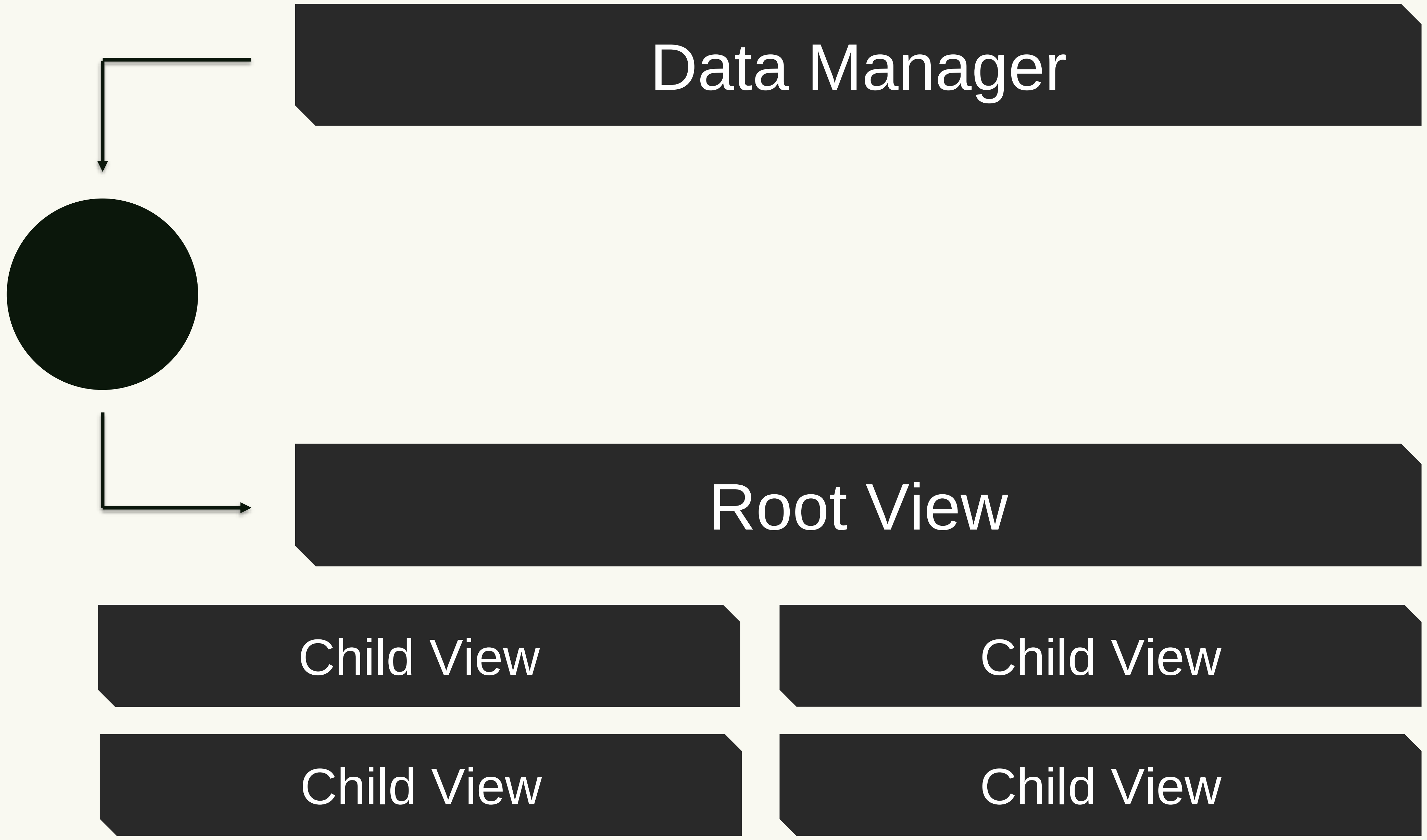
EXAMPLE: PYRSISTENT

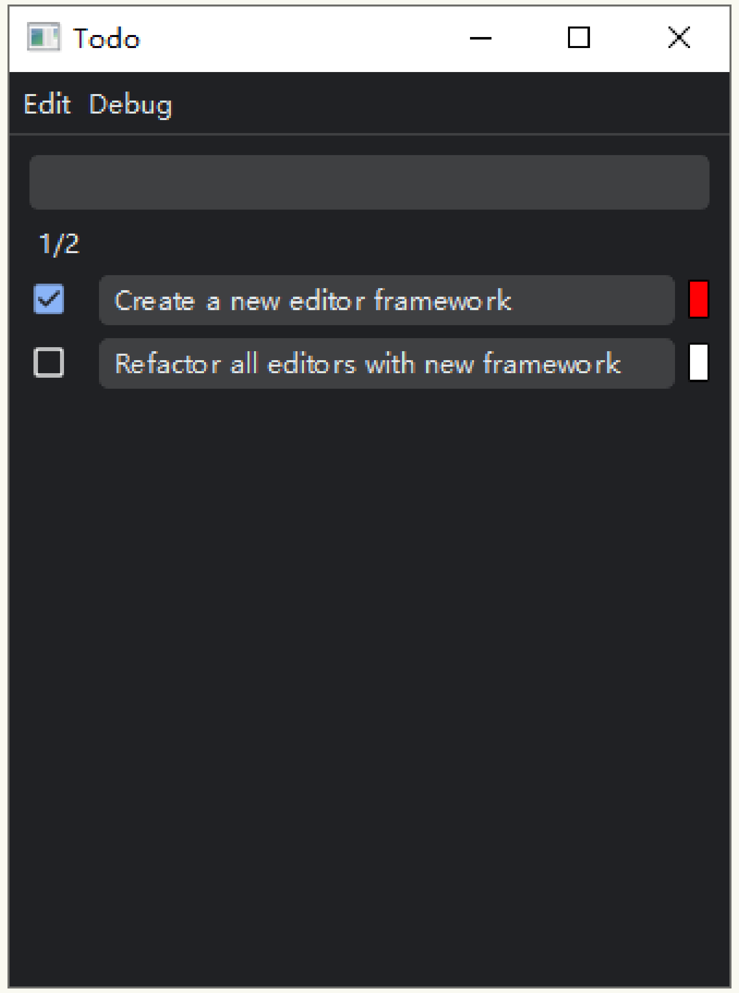


```python
class TodoItemData(PRecord):
    done = field(initial=False)
    content = field(initial="")
    color = field(initial=0xFFFFFF)

>> todo_item = TodoItemData()
>> print(todo_item)
>> {"done": False, "content": "", "color": 0xFFFFFF}
>> print(todo_item.done)
>> False
```

- Cheap copy
- Cheap diff
  - Replace comparing content with comparing memory location
  - Quickly to identify unchanged data


Data Manager
at fixed frame
view.refresh(data)
View


Data Manager
Root View
Child View
Child View
Child View
Child View

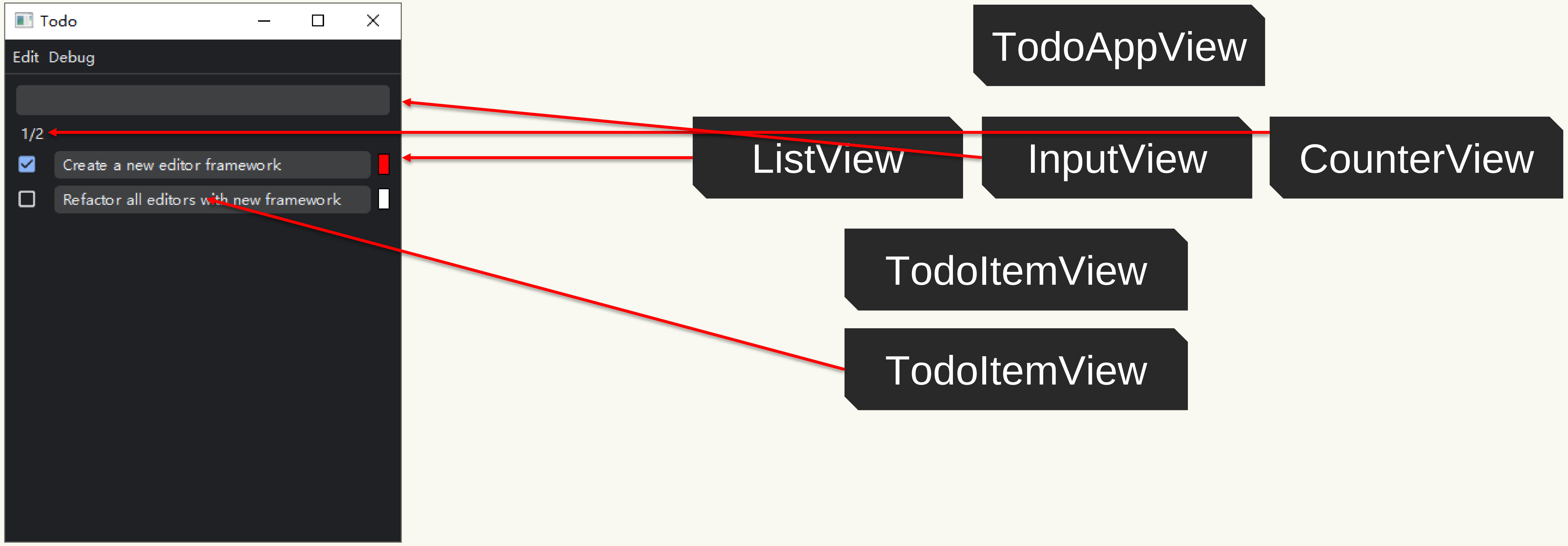


1/2

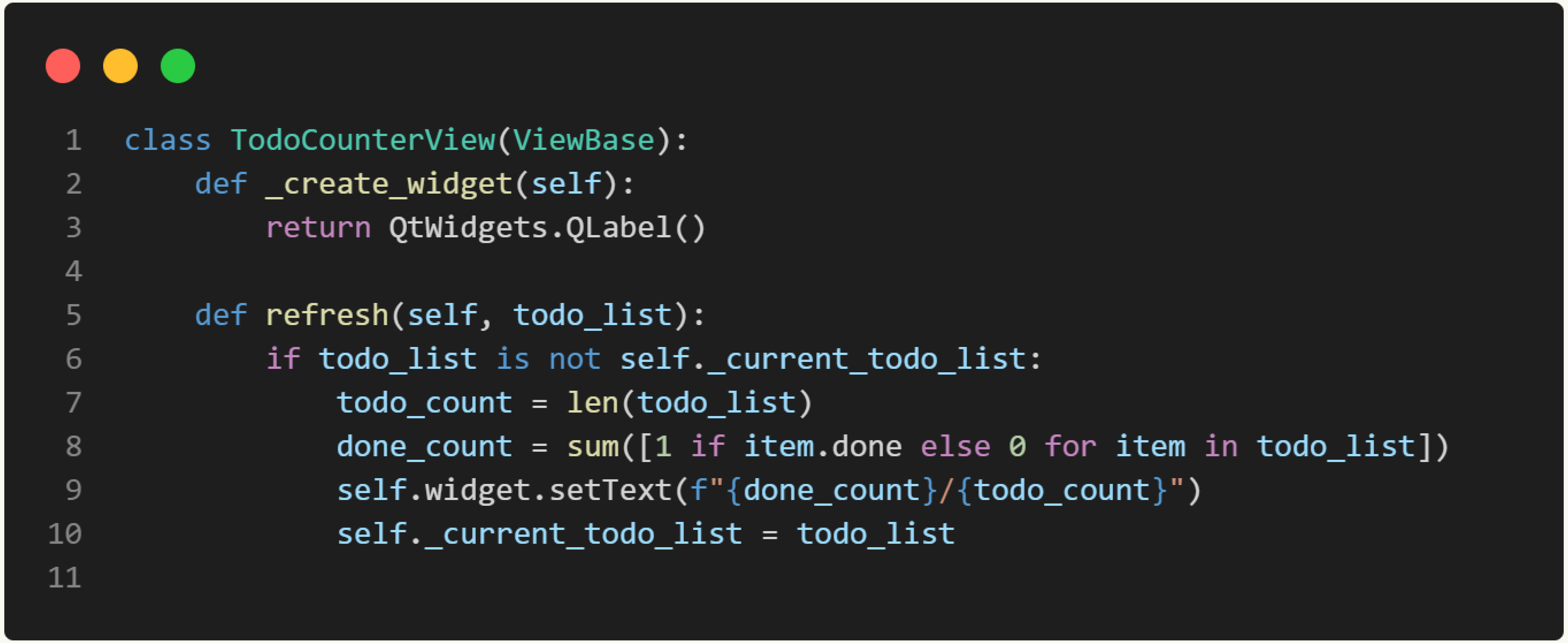
✓ Create a new editor framework

☐ Refactor all editors with new framework

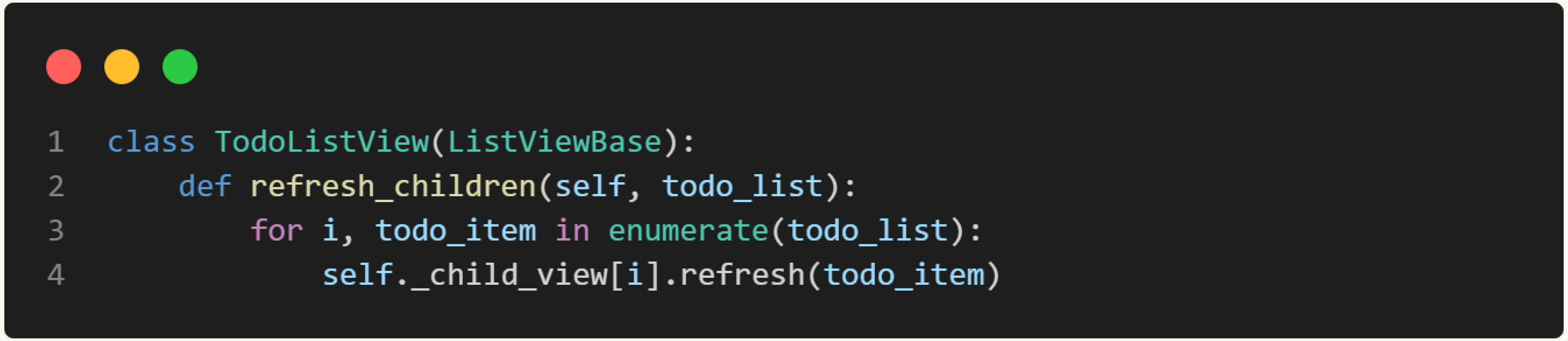
```python
class TodoItemData(RecordWithUUID):
    done = field()
    content = field()
    color = field()


class TodoAppData(PRecord):
    todo_list = field()   # a list of TodoItemData
```


Todo
Edit Debug
1/2
Create a new editor framework
Refactor all editors with new framework
TodoAppView
ListView
InputView
CounterView
TodoItemView
TodoItemView

```python
class TodoAppView(ViewBase):
    def refresh(self, todo_app_data):
        self._counter_view.refresh(todo_app_data.todo_list)
        self._list_view.refresh(todo_app_data.todo_list)
```



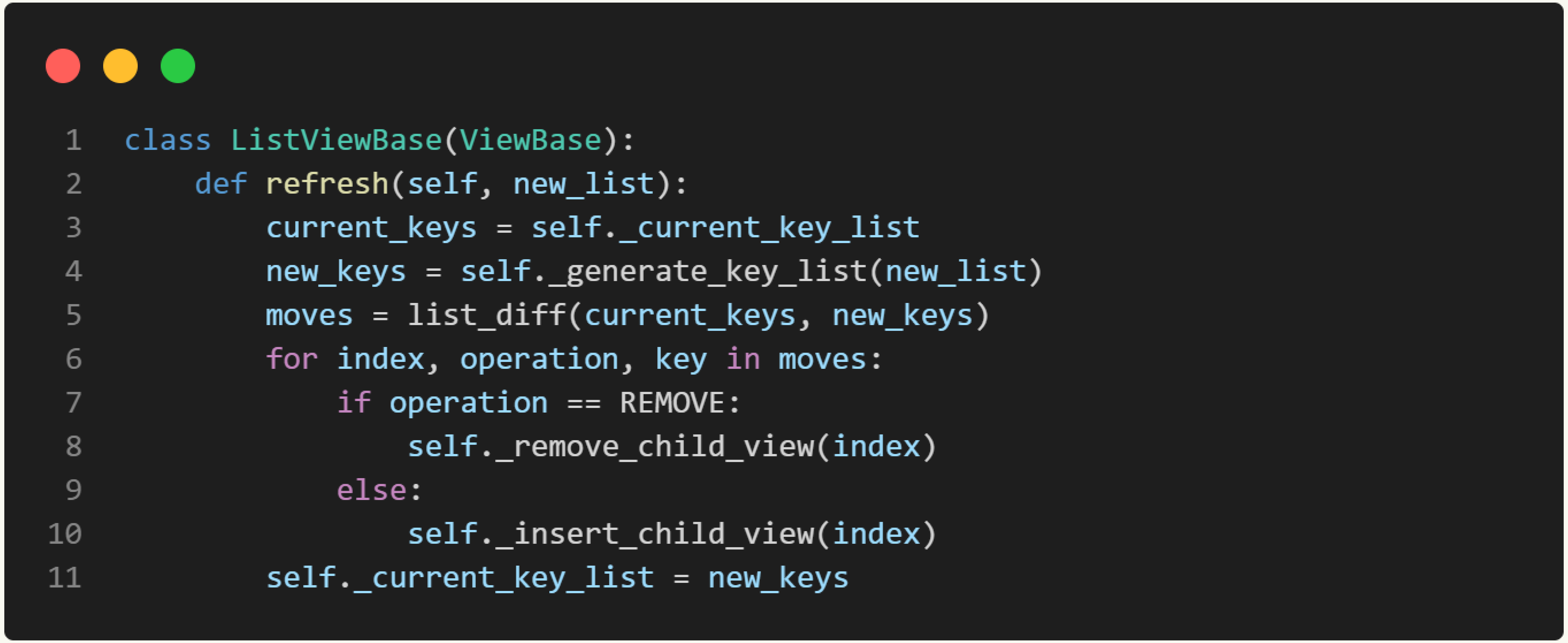
```python
class TodoCounterView(ViewBase):
    def _create_widget(self):
        return QtWidgets.QLabel()

    def refresh(self, todo_list):
        if todo_list is not self._current_todo_list:
            todo_count = len(todo_list)
            done_count = sum([1 if item.done else 0 for item in todo_list])
            self.widget.setText(f"{done_count}/{todo_count}")
            self._current_todo_list = todo_list

```



```python
class TodoListView(ListViewBase):
    def refresh_children(self, todo_list):
        for i, todo_item in enumerate(todo_list):
            self._child_view[i].refresh(todo_item)
```

```python
class TodoItemView(ViewBase):
    def refresh(self, todo_item):
        if todo_item is not self._current_todo_item:
            self._done_checkbox.setChecked(todo_item.done)
            self._push_button.setStyleSheet(
                LABEL_BUTTON.format(color=todo_item.color))
            self._content_edit.setText(todo_item.content)
            self._current_todo_item = todo_item
```

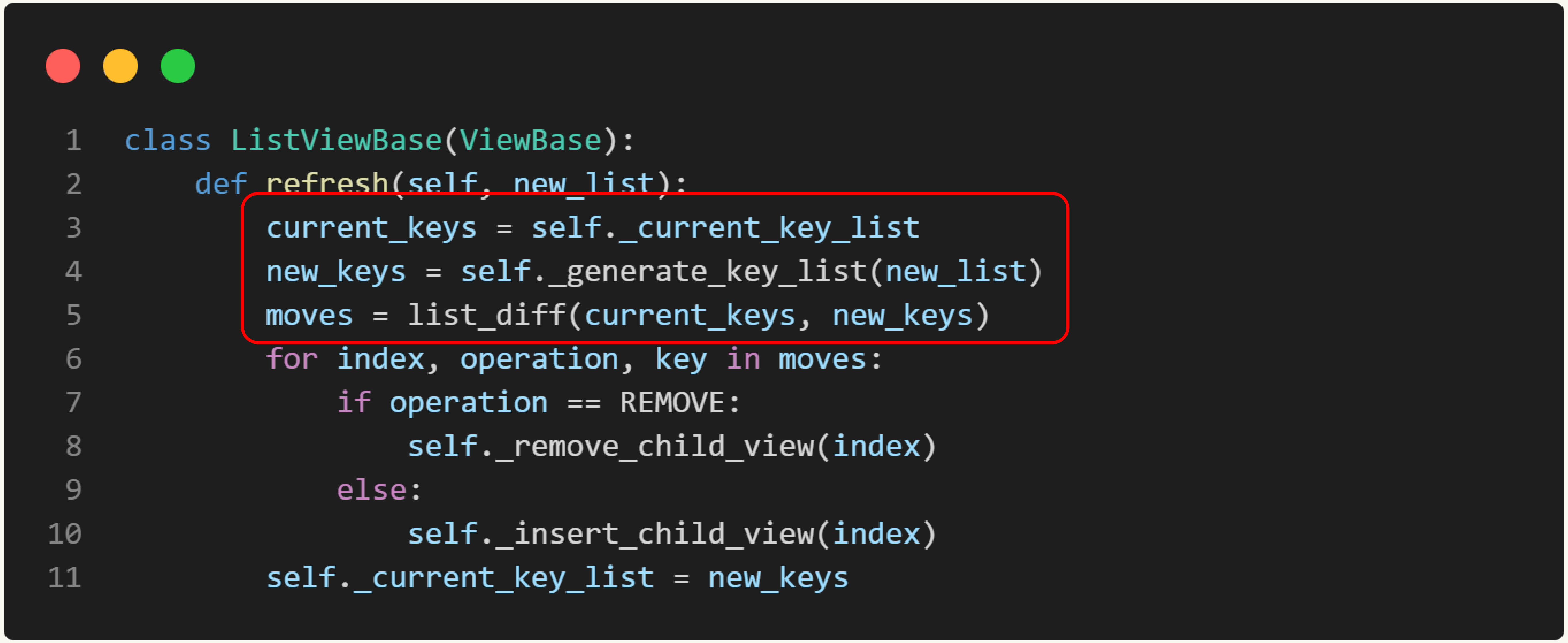
```python
class TodoItemView(ViewBase):
    def refresh(self, todo_item):
        if todo_item is not self._current_todo_item:
            self._done_checkbox.setChecked(todo_item.done)
            self._push_button.setStyleSheet(
                LABEL_BUTTON.format(color=todo_item.color))
            if todo_item.content is not self._current_todo_item.content:
                self._content_edit.setText(todo_item.content)
            self._current_todo_item = todo_item
```



```python
class ListViewBase(ViewBase):
    def refresh(self, new_list):
        current_keys = self._current_key_list
        new_keys = self._generate_key_list(new_list)
        moves = list_diff(current_keys, new_keys)
        for index, operation, key in moves:
            if operation == REMOVE:
                self._remove_child_view(index)
            else:
                self._insert_child_view(index)
        self._current_key_list = new_keys
```

LIST DIFF

- Inspired by list_diff in React
- Heuristic
- Remove operation before insert operation



```python
class ListViewBase(ViewBase):
    def refresh(self, new_list):
        current_keys = self._current_key_list
        new_keys = self._generate_key_list(new_list)
        moves = list_diff(current_keys, new_keys)
        for index, operation, key in moves:
            if operation == REMOVE:
                self._remove_child_view(index)
            else:
                self._insert_child_view(index)
        self._current_key_list = new_keys
```

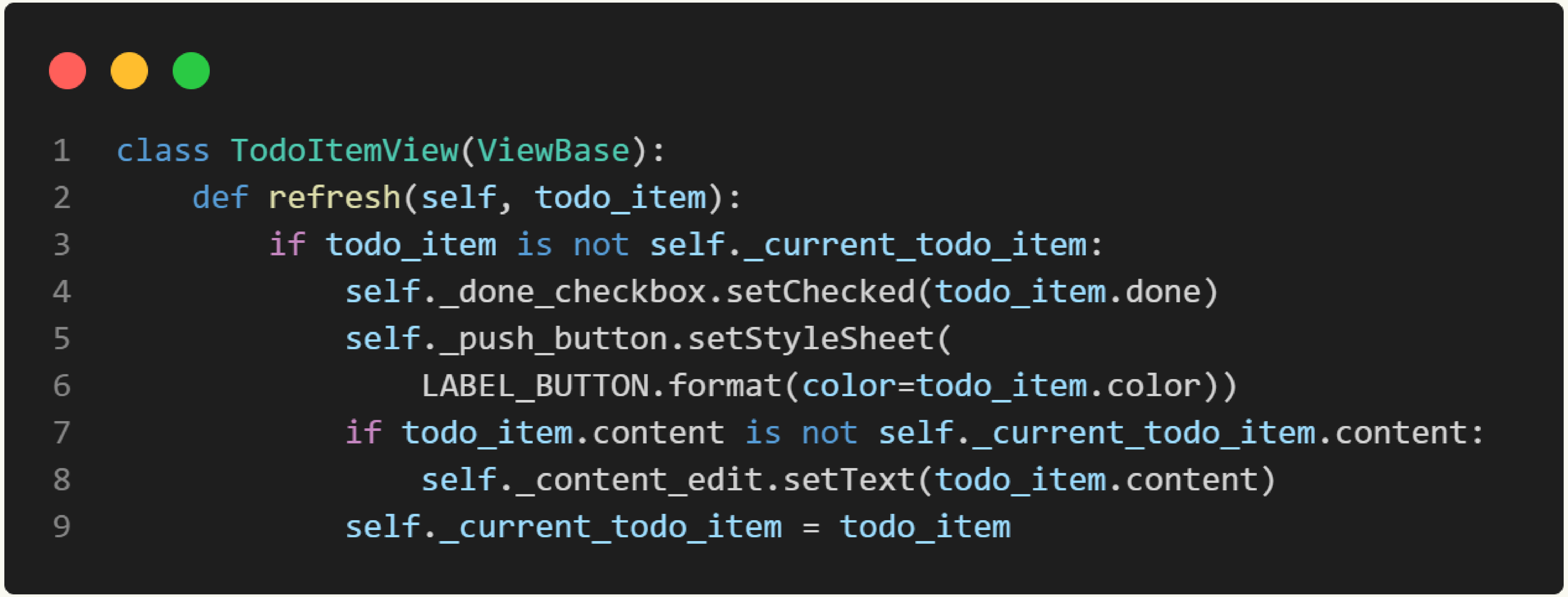
LIST DIFF

```
[TodoItemData(id_=1, done=False)]

[TodoItemData(id_=1, done=True)]

(DEL, TodoItemData(id_=1, done=False))

(ADD, TodoItemData(id_=1, done=True))
```

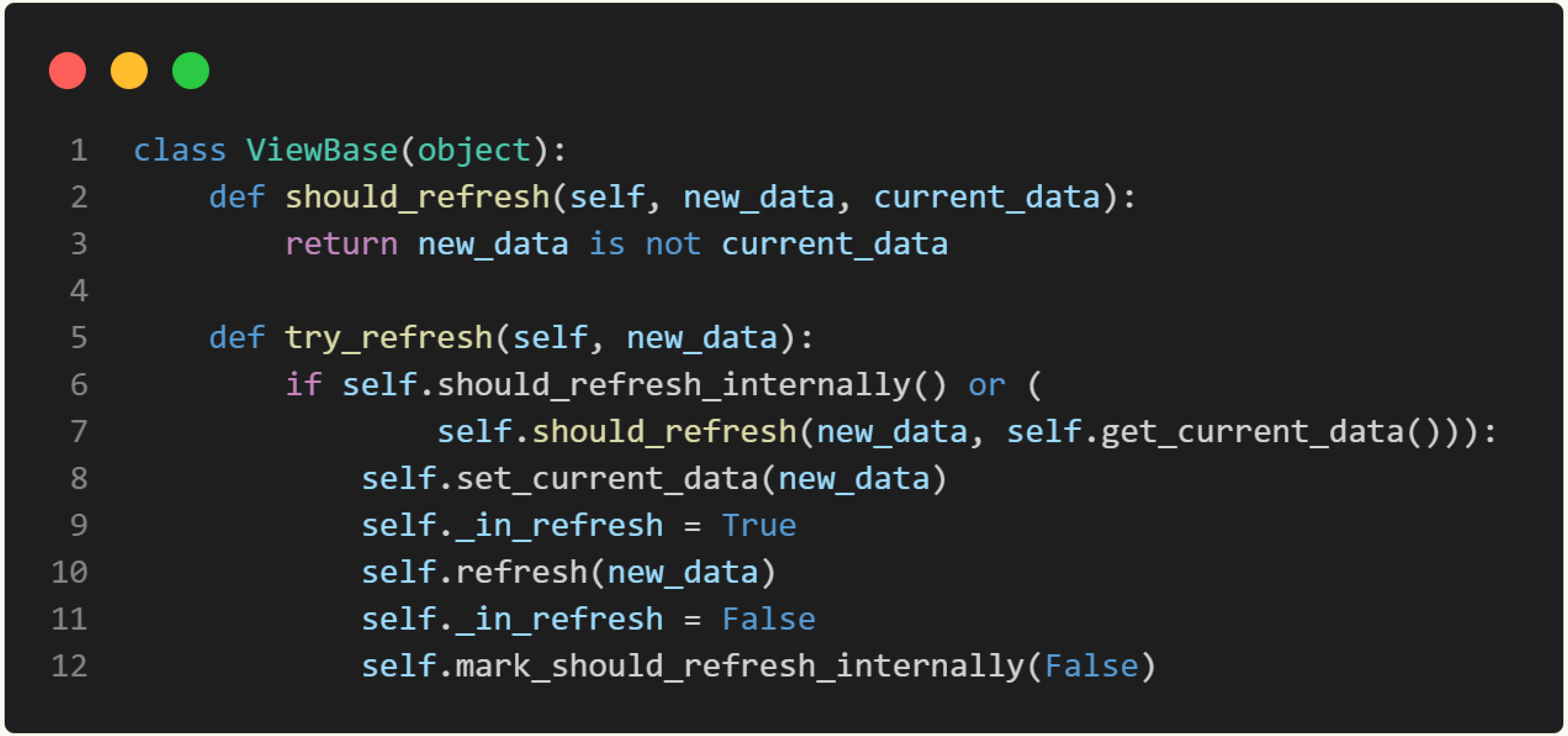
LIST DIFF

[1]

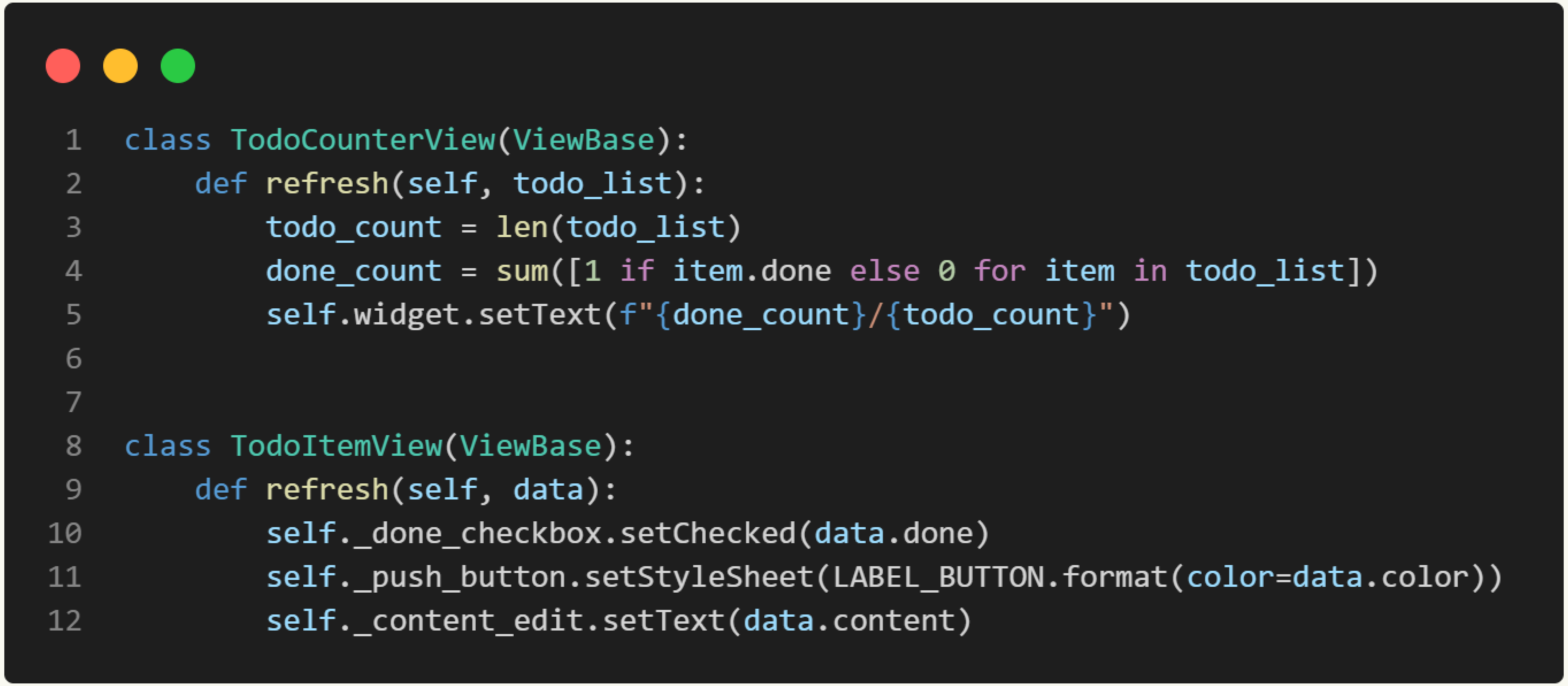
[1]



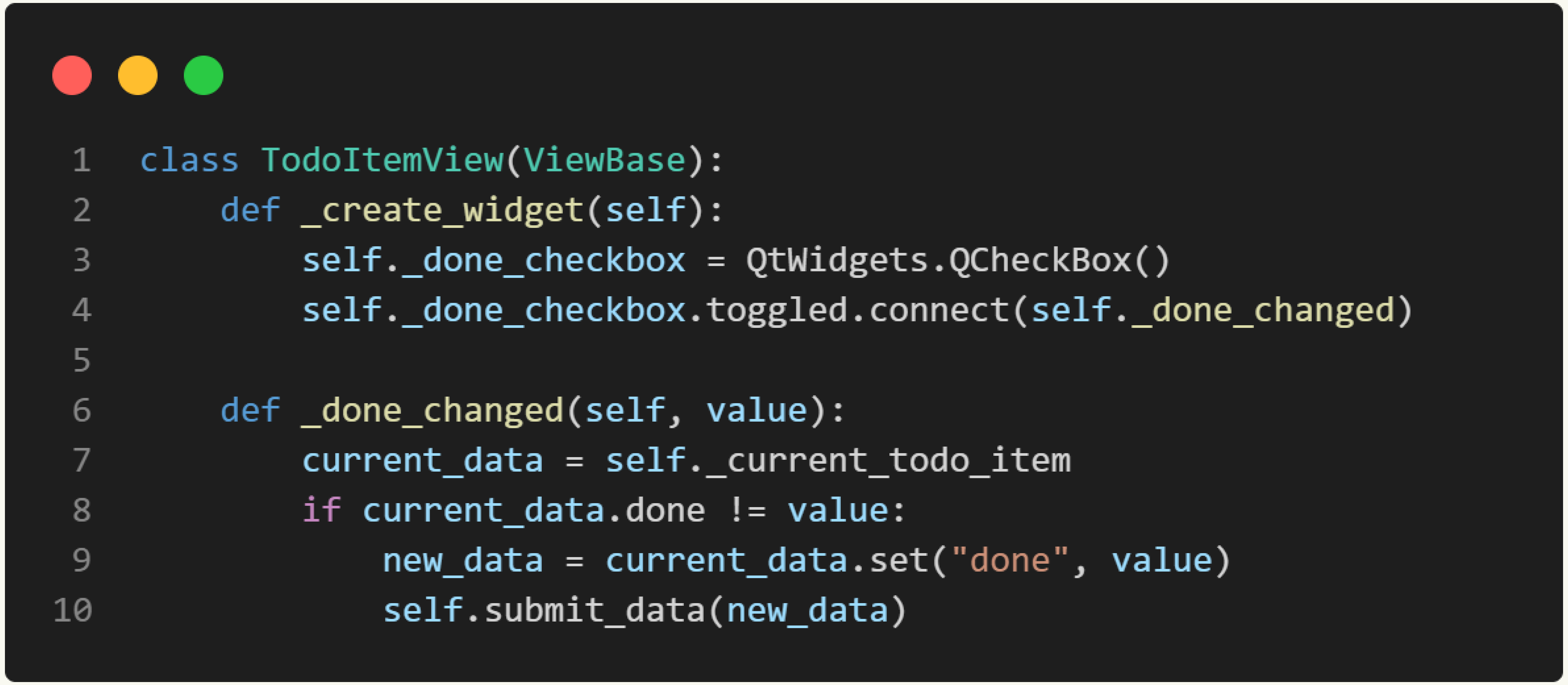
```python
class TodoItemView(ViewBase):
    def refresh(self, todo_item):
        if todo_item is not self._current_todo_item:
            self._done_checkbox.setChecked(todo_item.done)
            self._push_button.setStyleSheet(
                LABEL_BUTTON.format(color=todo_item.color))
            if todo_item.content is not self._current_todo_item.content:
                self._content_edit.setText(todo_item.content)
            self._current_todo_item = todo_item
```



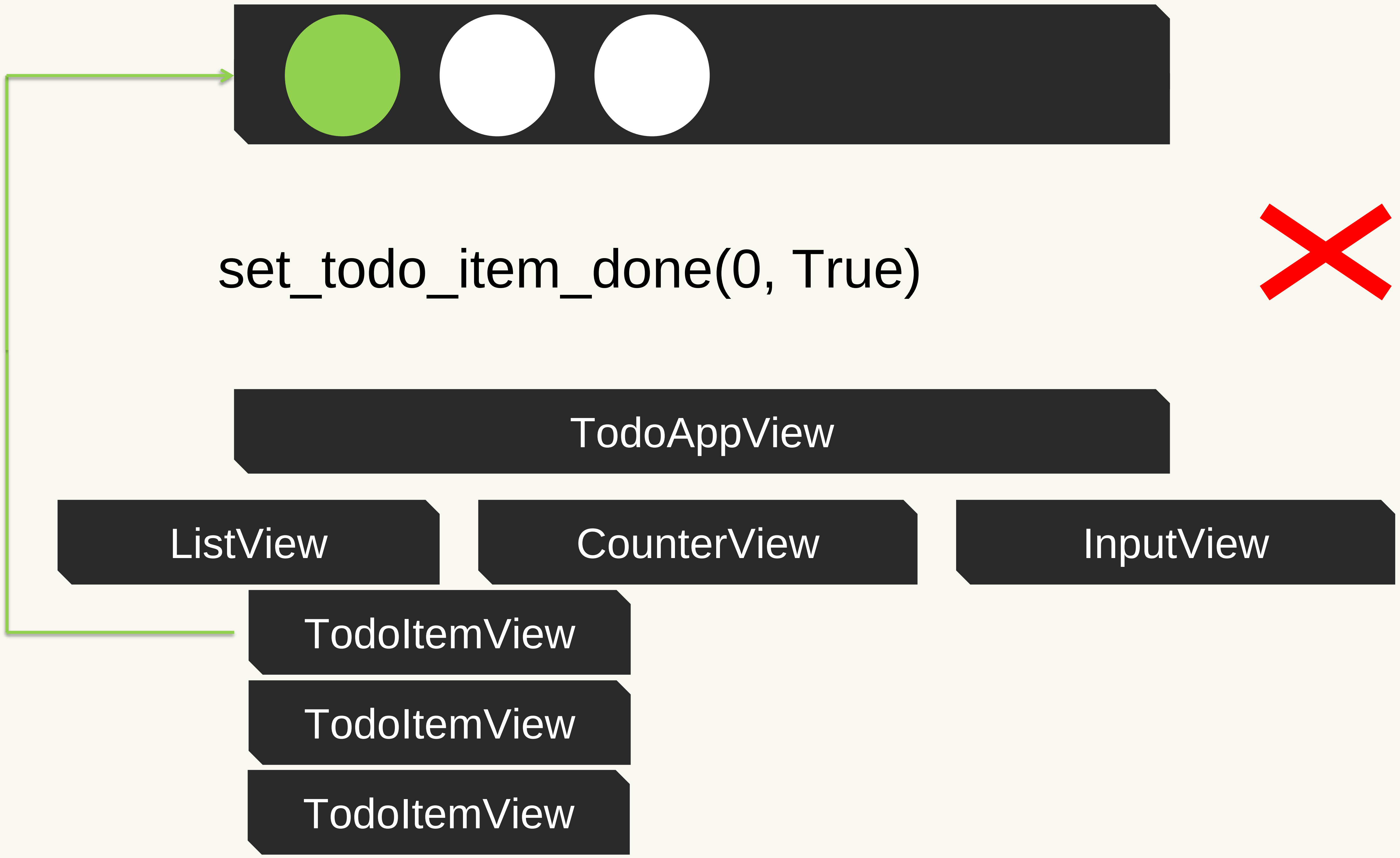
```python
class ViewBase(object):
    def should_refresh(self, new_data, current_data):
        return new_data is not current_data

    def try_refresh(self, new_data):
        if self.should_refresh_internally() or (
                self.should_refresh(new_data, self.get_current_data())):
            self.set_current_data(new_data)
            self._in_refresh = True
            self.refresh(new_data)
            self._in_refresh = False
            self.mark_should_refresh_internally(False)
```

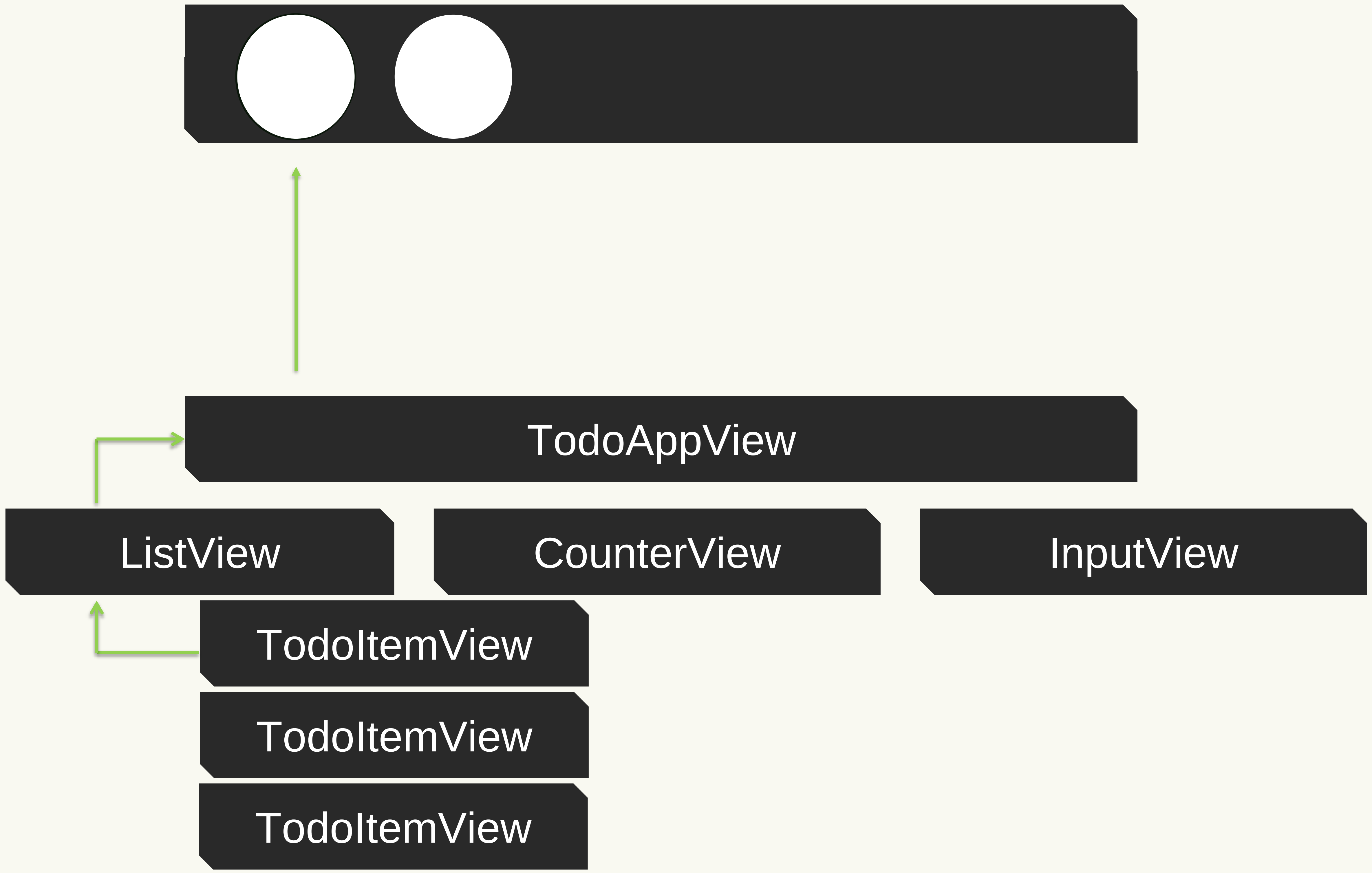


```python
class TodoCounterView(ViewBase):
    def refresh(self, todo_list):
        todo_count = len(todo_list)
        done_count = sum([1 if item.done else 0 for item in todo_list])
        self.widget.setText(f"{done_count}/{todo_count}")


class TodoItemView(ViewBase):
    def refresh(self, data):
        self._done_checkbox.setChecked(data.done)
        self._push_button.setStyleSheet(LABEL_BUTTON.format(color=data.color))
        self._content_edit.setText(data.content)
```



```python
class TodoItemView(ViewBase):
    def _create_widget(self):
        self._done_checkbox = QtWidgets.QCheckBox()
        self._done_checkbox.toggled.connect(self._done_changed)

    def _done_changed(self, value):
        current_data = self._current_todo_item
        if current_data.done != value:
            new_data = current_data.set("done", value)
            self.submit_data(new_data)
```

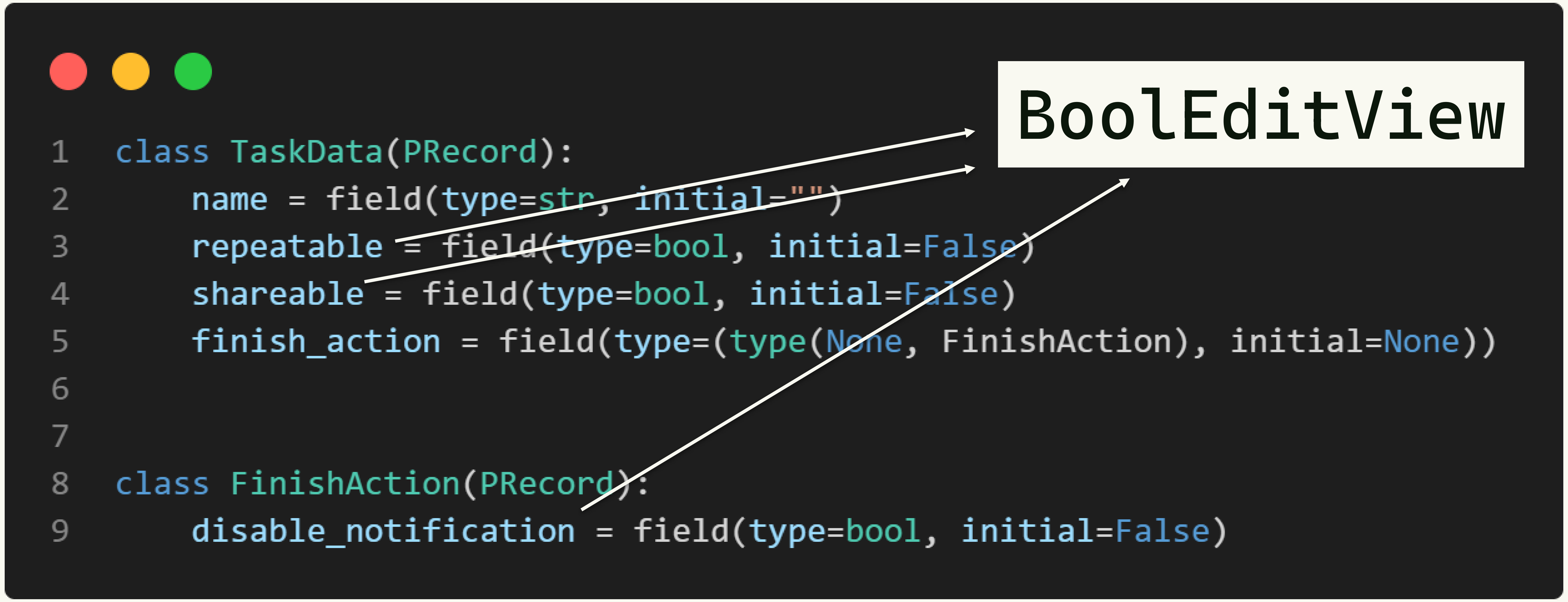

set_todo_item_done(0, True)
TodoAppView
ListView
CounterView
InputView
TodoItemView
TodoItemView
TodoItemView


TodoAppView
ListView
CounterView
InputView
TodoItemView
TodoItemView
TodoItemView

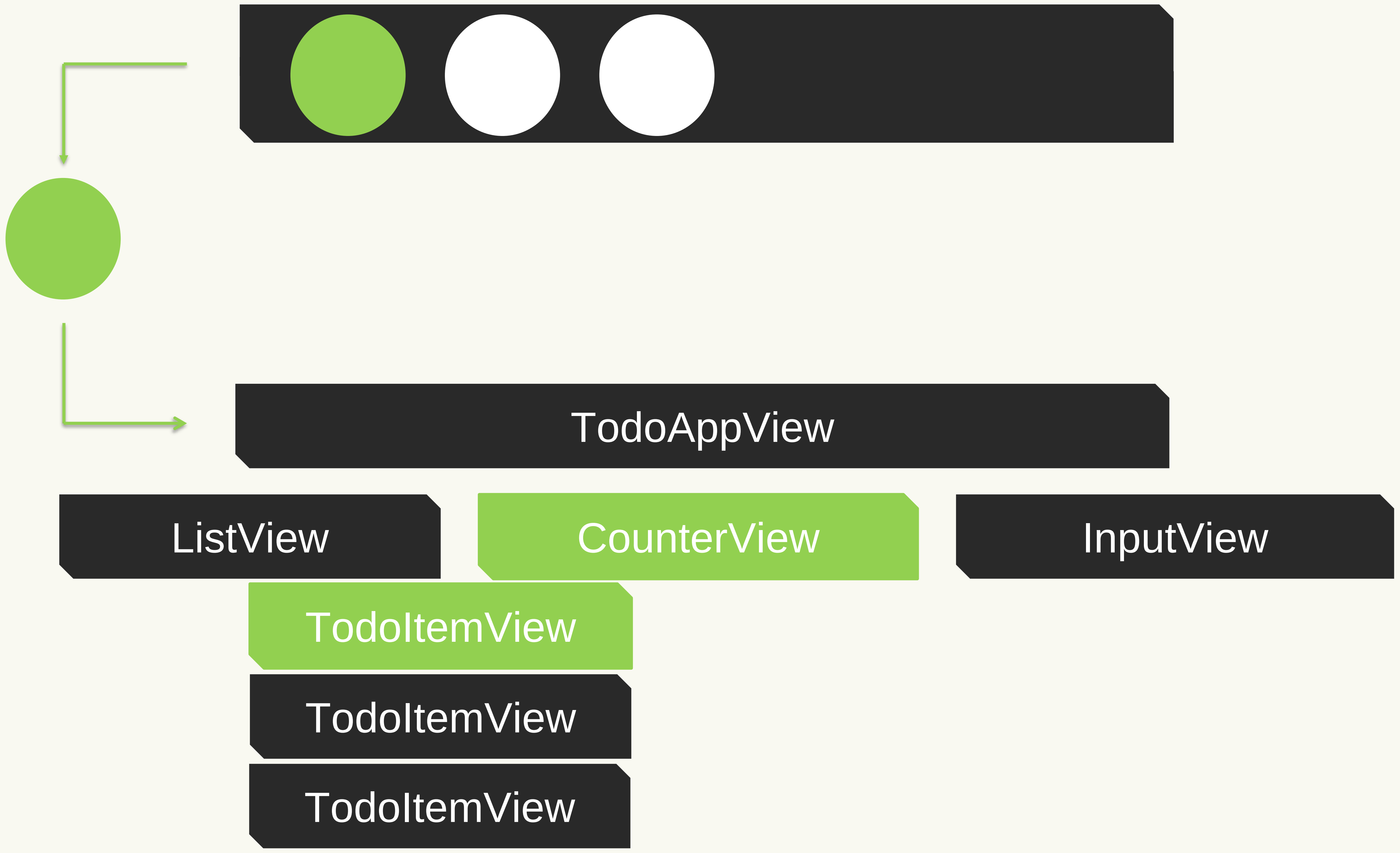
SUBMIT DATA

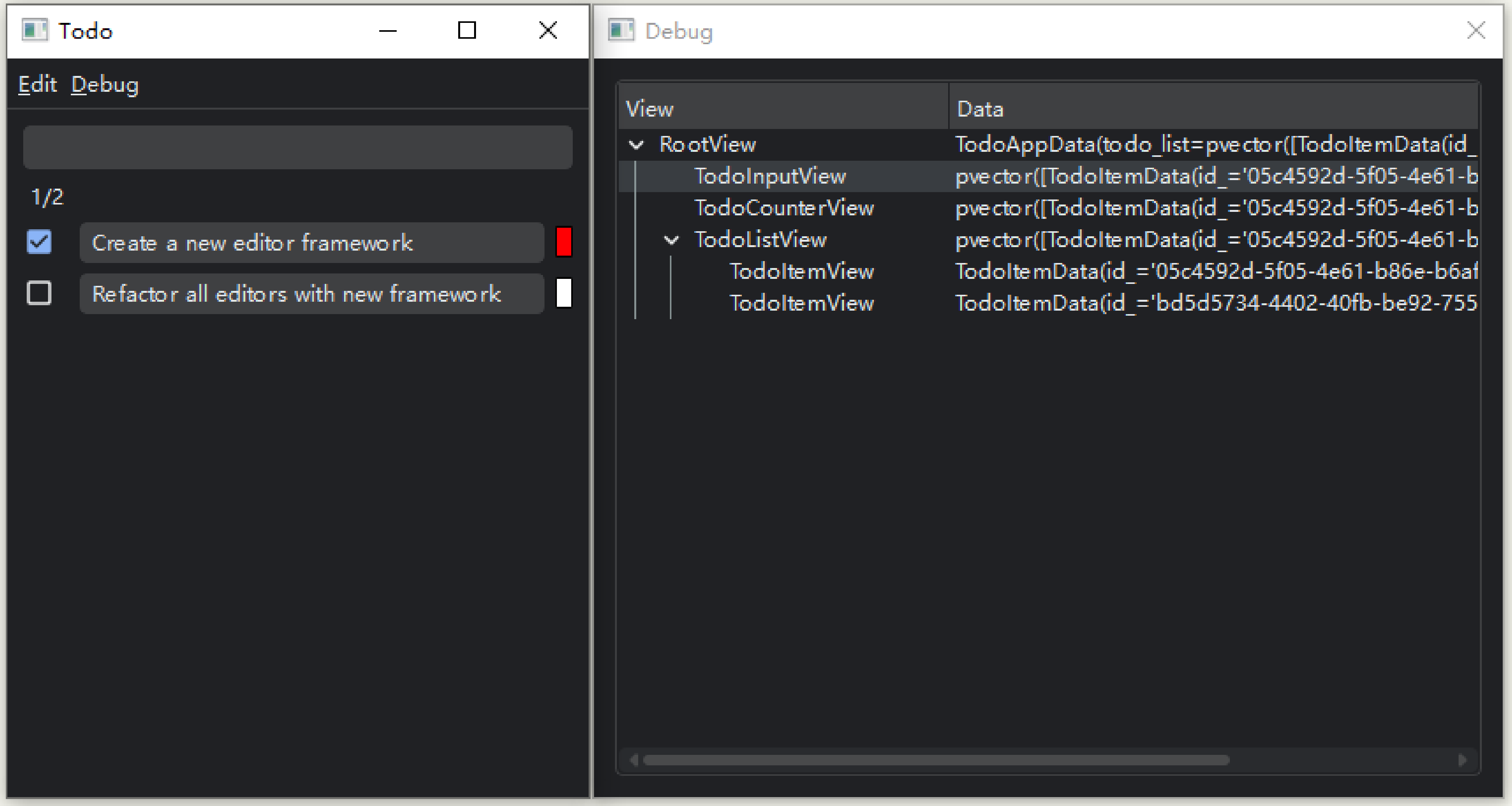
- Always submit data to parent
- Zero dependency to other classes
- Maximize reusability

SUBMIT DATA



```
class TaskData(PRecord):
    name = field(type=str, initial="")
    repeatable = field(type=bool, initial=False)
    shareable = field(type=bool, initial=False)
    finish_action = field(type=(type(None), FinishAction), initial=None))


class FinishAction(PRecord):
    disable_notification = field(type=bool, initial=False)
```


TodoAppView
ListView
CounterView
InputView
TodoItemView
TodoItemView
TodoItemView

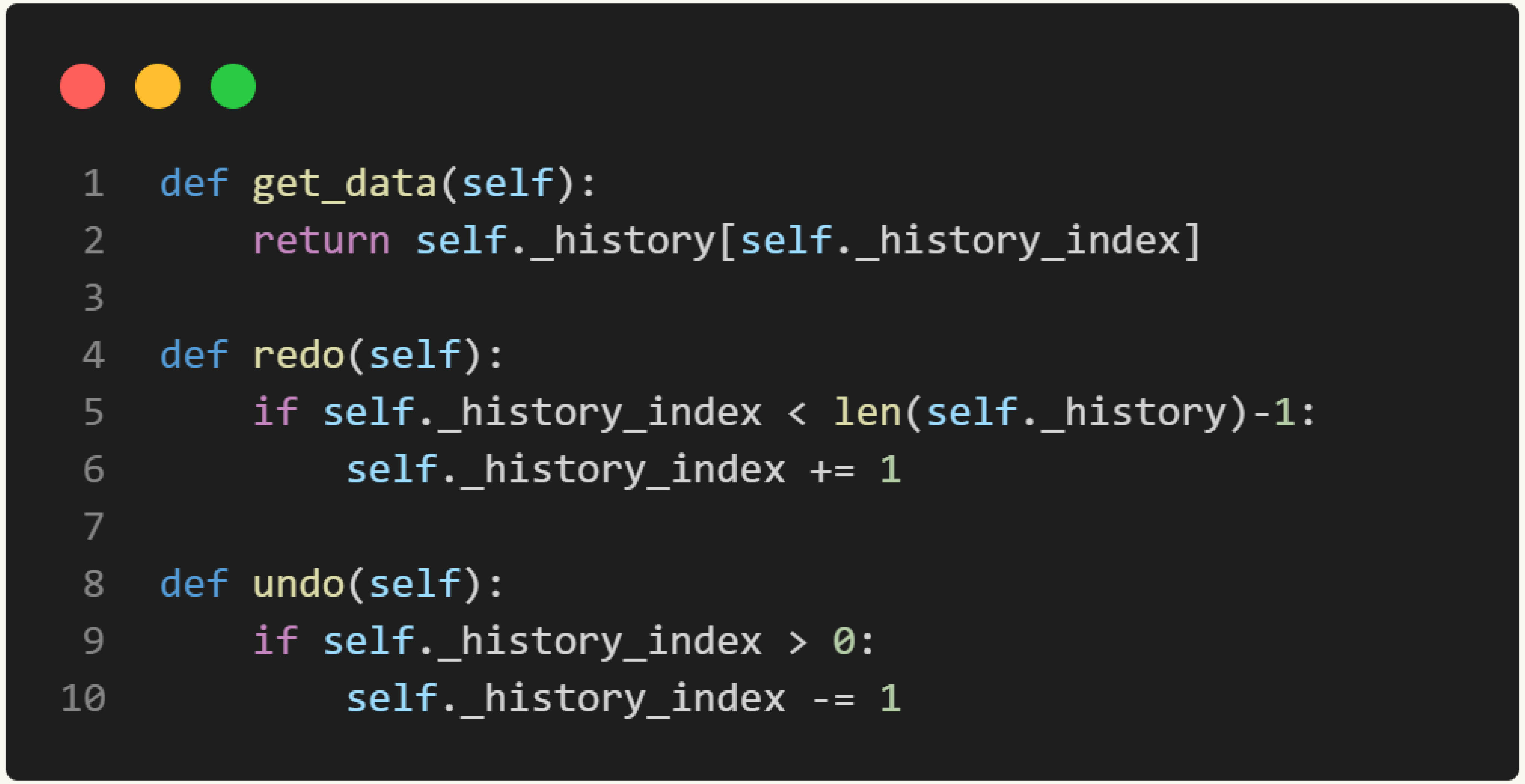


1/2

- [x] Create a new editor framework
- [ ] Refactor all editors with new framework

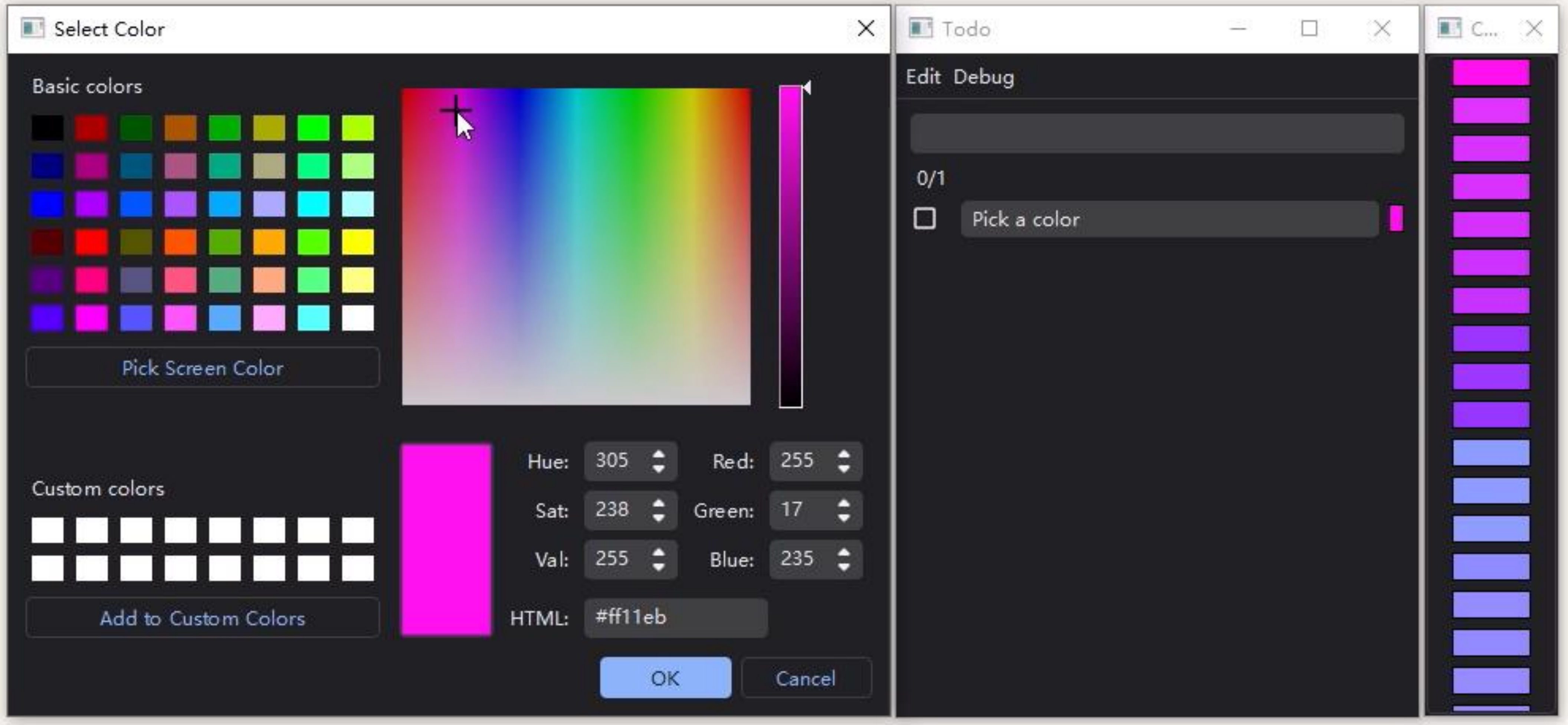
View	Data
RootView	TodoAppData(todo_list=pvector([TodoItemData(id_
TodoInputView	pvector([TodoItemData(id_='05c4592d-5f05-4e61-b
TodoCounterView	pvector([TodoItemData(id_='05c4592d-5f05-4e61-b
TodoListView	pvector([TodoItemData(id_='05c4592d-5f05-4e61-b
TodoItemView	TodoItemData(id_='05c4592d-5f05-4e61-b86e-b6af
TodoItemView	TodoItemData(id_='bd5d5734-4402-40fb-be92-755

UNDO/REDO



```python
def get_data(self):
    return self._history[self._history_index]

def redo(self):
    if self._history_index < len(self._history)-1:
        self._history_index += 1

def undo(self):
    if self._history_index > 0:
        self._history_index -= 1
```

PREVIEW CHANGES

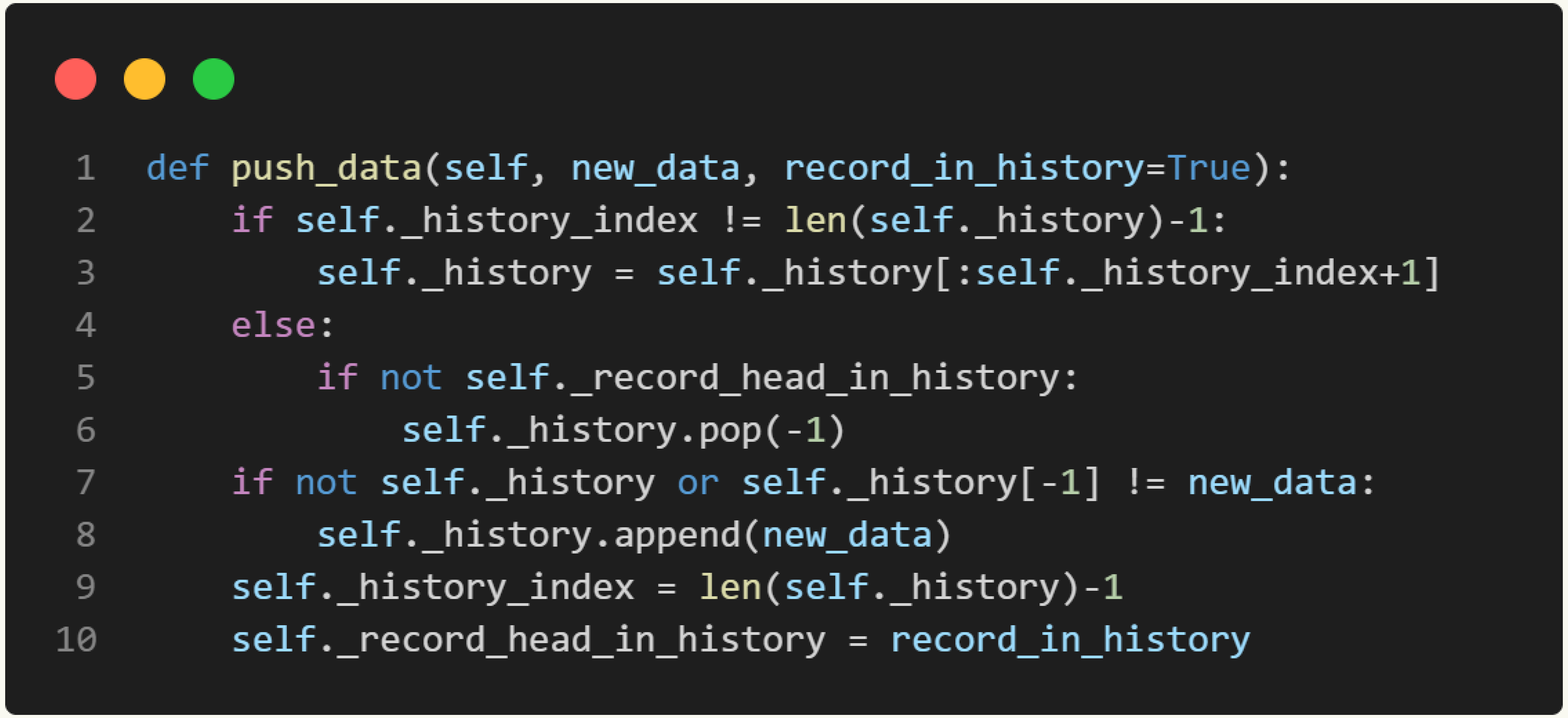


Hue: 305
Sat: 238
Val: 255
Red: 255
Green: 17
Blue: 235
HTML: #ff11eb

0/1

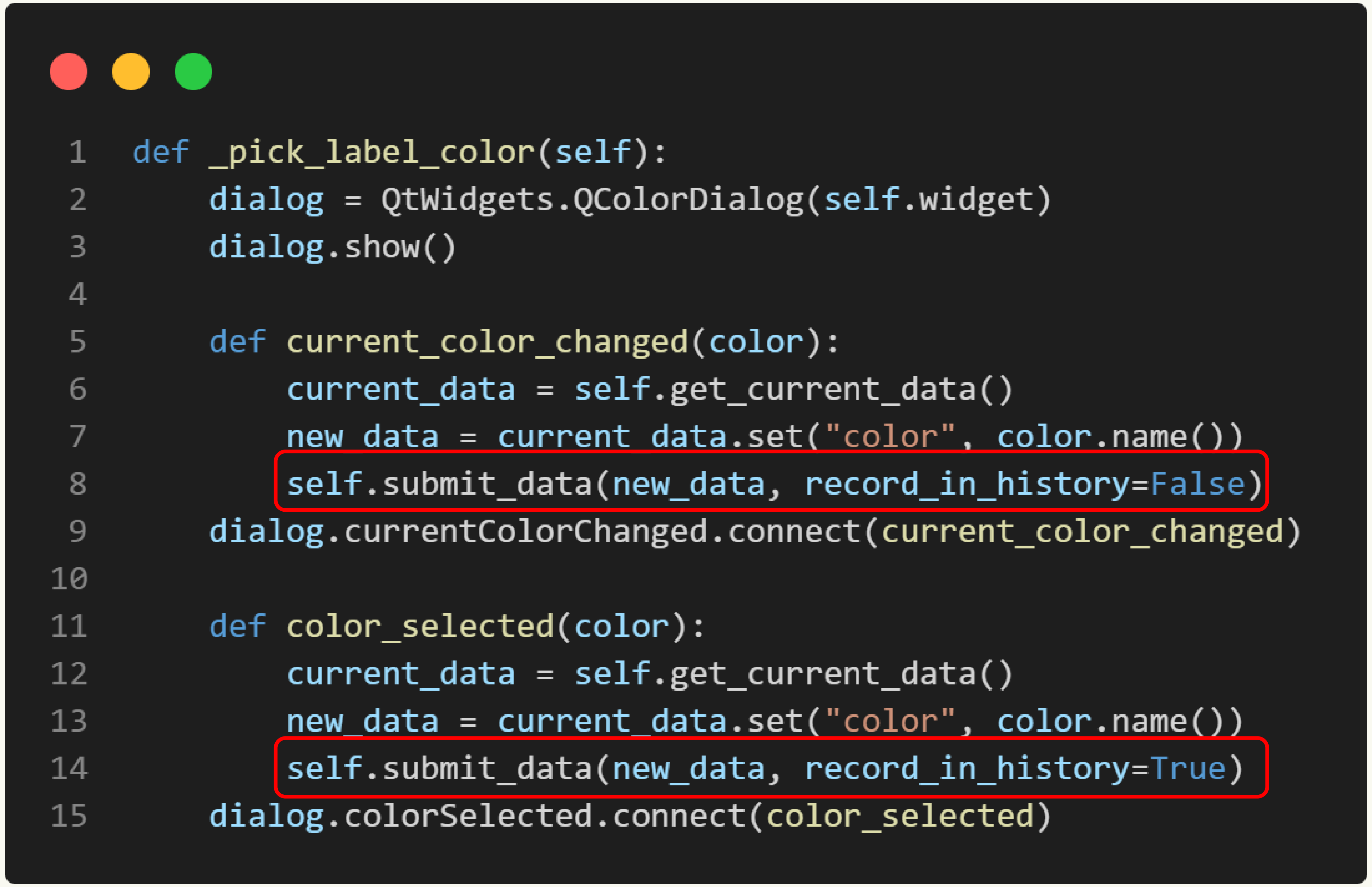
Pick a color

UNDO/REDO

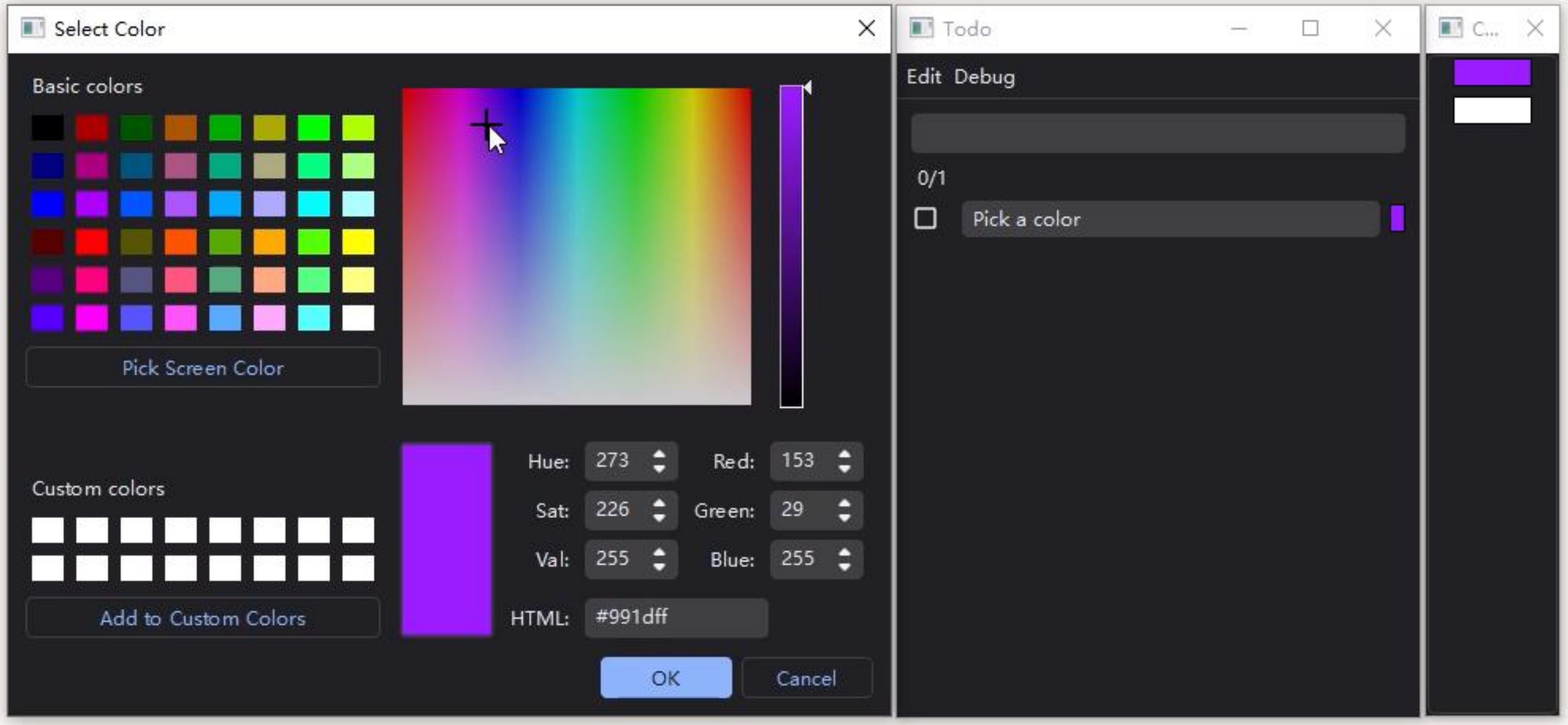


```python
def push_data(self, new_data, record_in_history=True):
    if self._history_index != len(self._history)-1:
        self._history = self._history[:self._history_index+1]
    else:
        if not self._record_head_in_history:
            self._history.pop(-1)
    if not self._history or self._history[-1] != new_data:
        self._history.append(new_data)
    self._history_index = len(self._history)-1
    self._record_head_in_history = record_in_history
```

UNDO/REDO



```python
def _pick_label_color(self):
    dialog = QtWidgets.QColorDialog(self.widget)
    dialog.show()

    def current_color_changed(color):
        current_data = self.get_current_data()
        new_data = current_data.set("color", color.name())
        self.submit_data(new_data, record_in_history=False)
    dialog.currentColorChanged.connect(current_color_changed)

    def color_selected(color):
        current_data = self.get_current_data()
        new_data = current_data.set("color", color.name())
        self.submit_data(new_data, record_in_history=True)
    dialog.colorSelected.connect(color_selected)
```

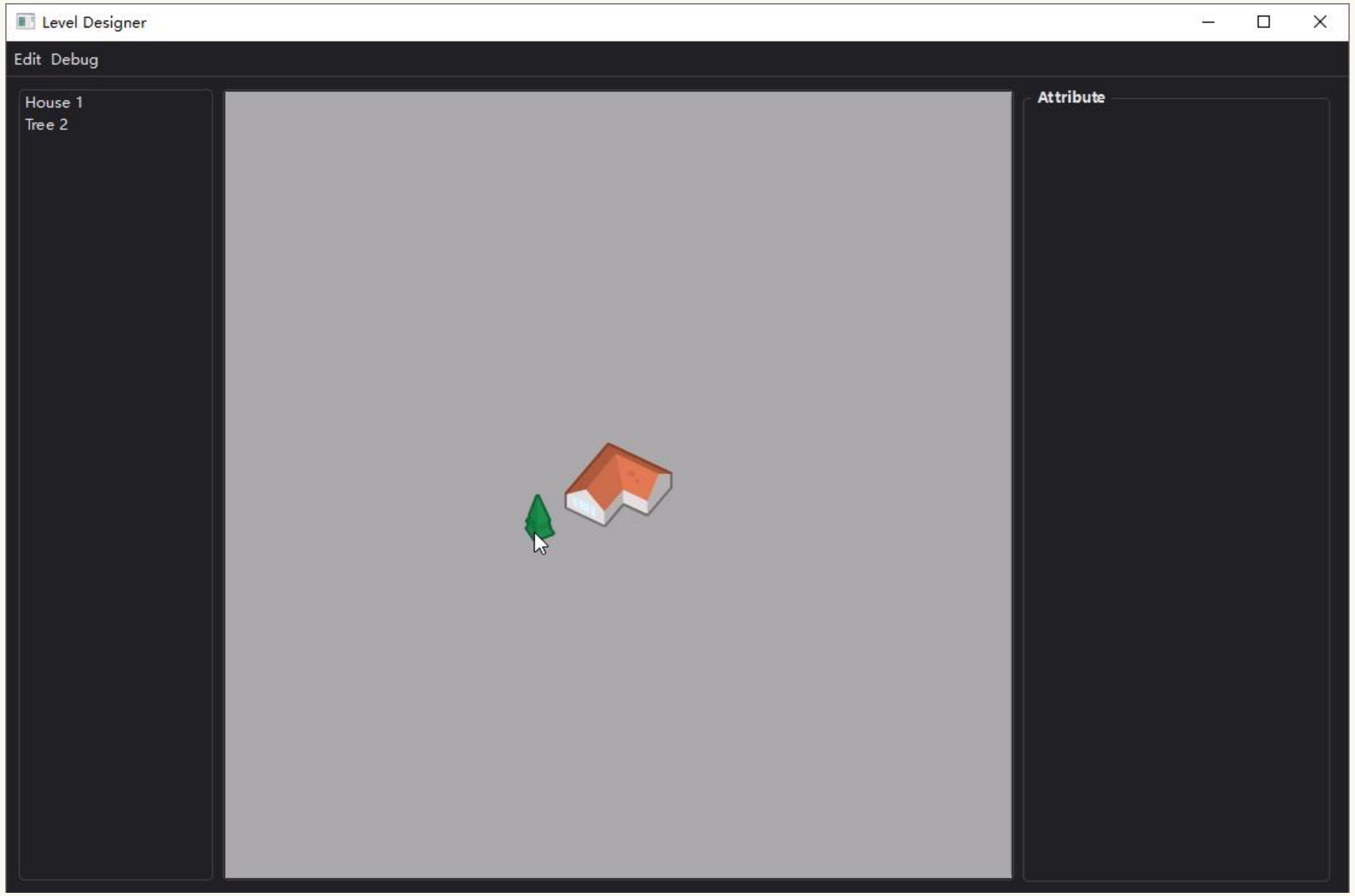


Hue: 273
Sat: 226
Val: 255
Red: 153
Green: 29
Blue: 255
HTML: #991dff

0/1

Pick a color

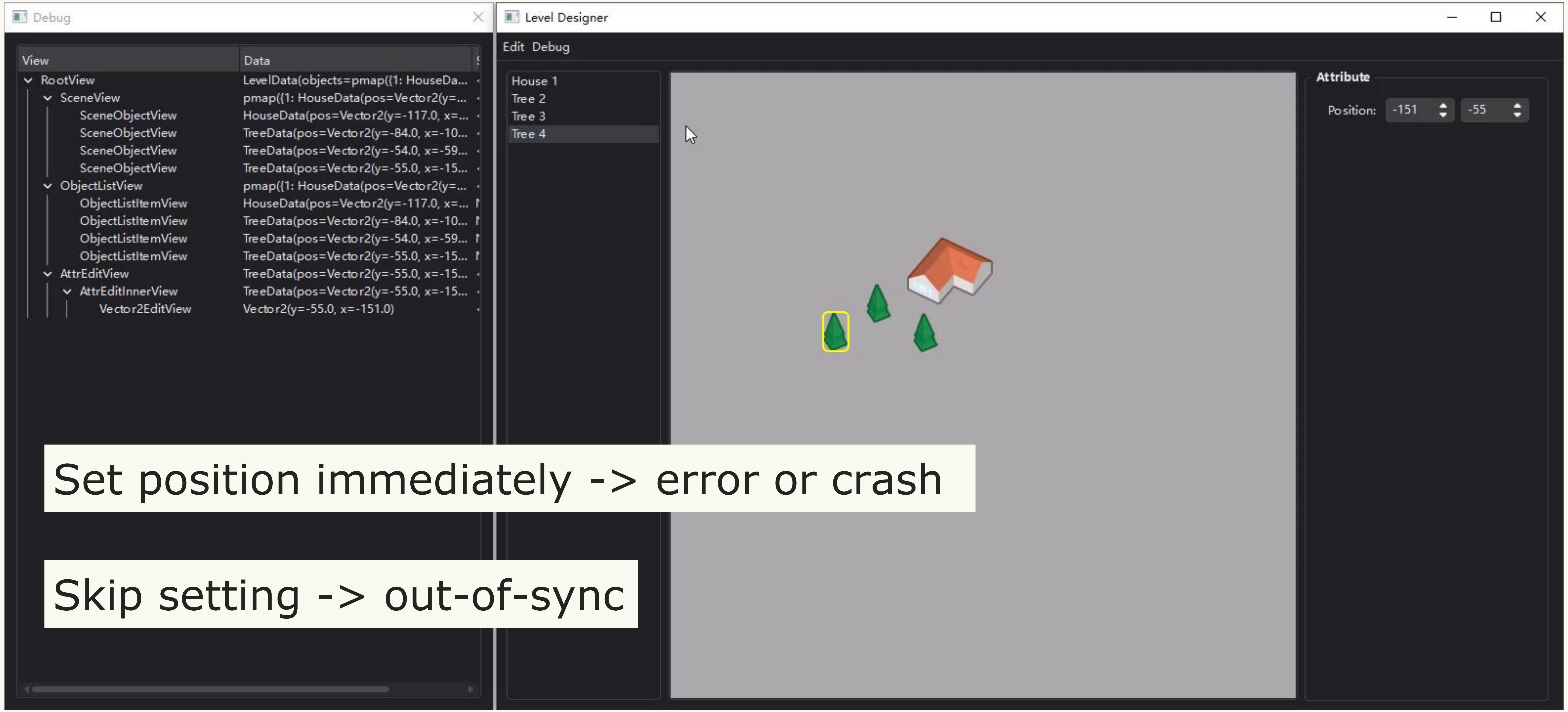
CONTINUOUS CHANGE



What about 3D models?

3D models are actually UIs

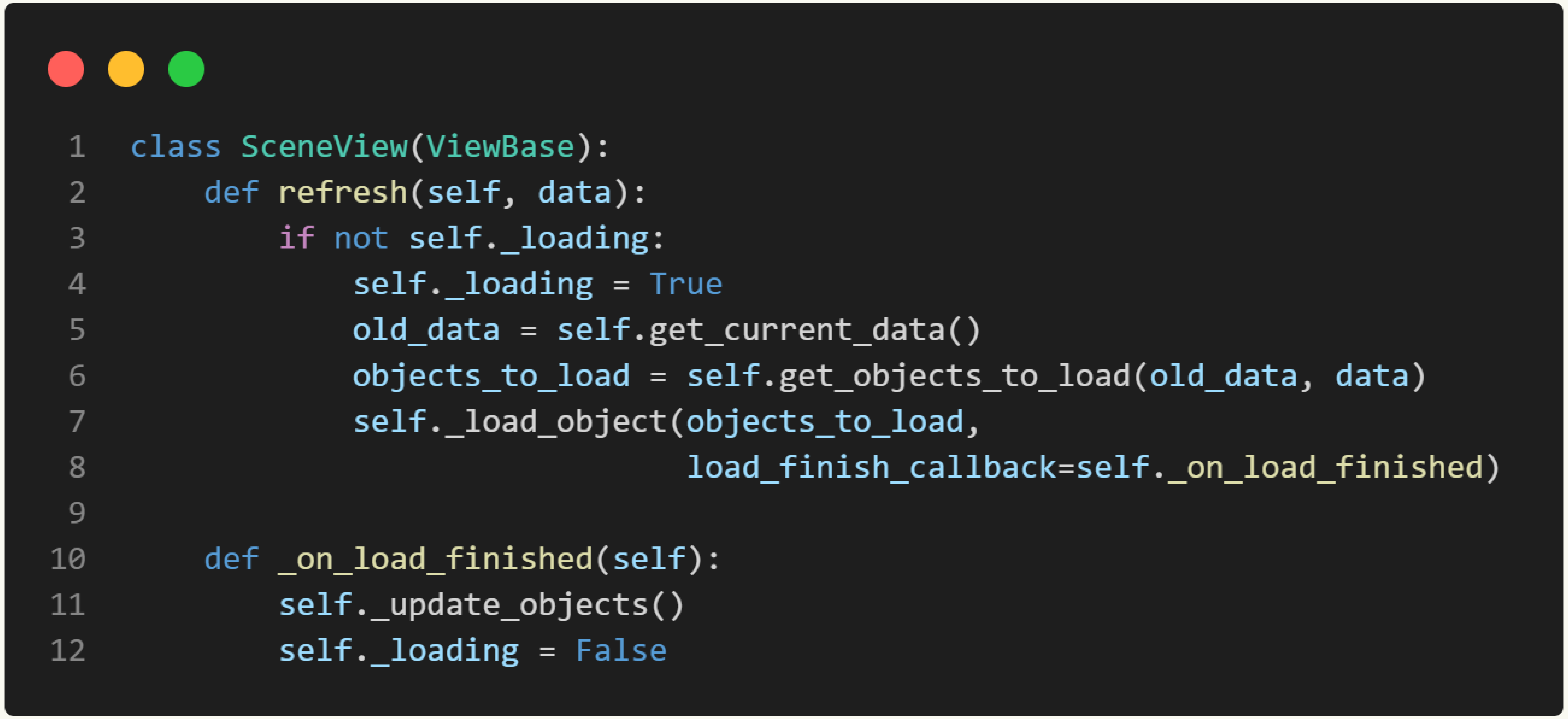
Decouple UI update with data update



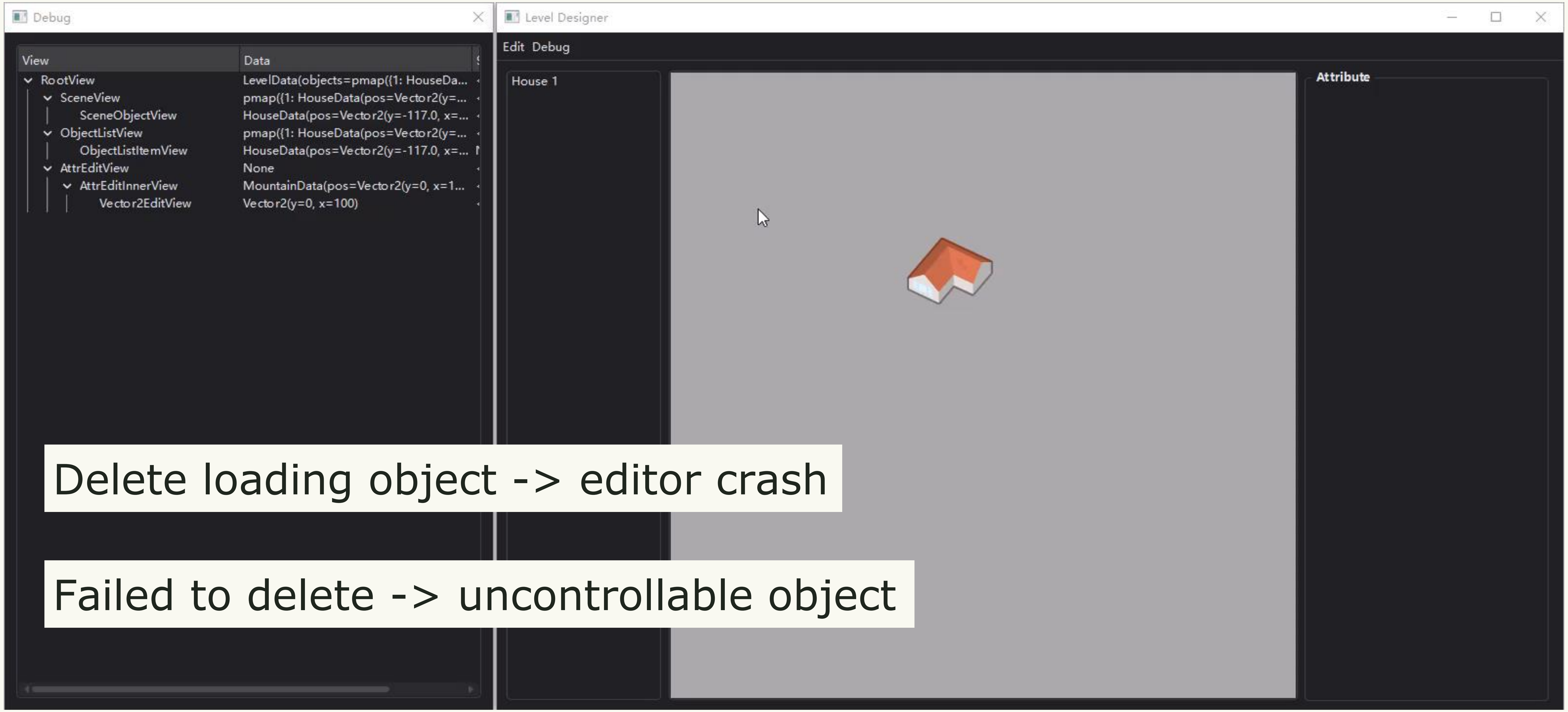
```
View                          Data
RootView                      LevelData(objects=pmap({1: HouseDa...
  SceneView                   pmap({1: HouseData(pos=Vector2(y=...
    SceneObjectView           HouseData(pos=Vector2(y=-117.0, x=...
    SceneObjectView           TreeData(pos=Vector2(y=-84.0, x=-10...
    SceneObjectView           TreeData(pos=Vector2(y=-54.0, x=-59...
    SceneObjectView           TreeData(pos=Vector2(y=-55.0, x=-15...
  ObjectListView              pmap({1: HouseData(pos=Vector2(y=...
    ObjectListItemView        HouseData(pos=Vector2(y=-117.0, x=...
    ObjectListItemView        TreeData(pos=Vector2(y=-84.0, x=-10...
    ObjectListItemView        TreeData(pos=Vector2(y=-54.0, x=-59...
    ObjectListItemView        TreeData(pos=Vector2(y=-55.0, x=-15...
  AttrEditView                TreeData(pos=Vector2(y=-55.0, x=-15...
    AttrEditInnerView         TreeData(pos=Vector2(y=-55.0, x=-15...
      Vector2EditView         Vector2(y=-55.0, x=-151.0)
```

Set position immediately -> error or crash

Skip setting -> out-of-sync



```python
class SceneView(ViewBase):
    def refresh(self, data):
        if not self._loading:
            self._loading = True
            old_data = self.get_current_data()
            objects_to_load = self.get_objects_to_load(old_data, data)
            self._load_object(objects_to_load,
                              load_finish_callback=self._on_load_finished)

    def _on_load_finished(self):
        self._update_objects()
        self._loading = False
```



View	Data
RootView	LevelData(objects=pmap({1: HouseDa...
SceneView	pmap({1: HouseData(pos=Vector2(y=...
SceneObjectView	HouseData(pos=Vector2(y=-117.0, x=...
ObjectListView	pmap({1: HouseData(pos=Vector2(y=...
ObjectListItemView	HouseData(pos=Vector2(y=-117.0, x=...
AttrEditView	None
AttrEditInnerView	MountainData(pos=Vector2(y=0, x=1...
Vector2EditView	Vector2(y=0, x=100)

Delete loading object -> editor crash

Failed to delete -> uncontrollable object

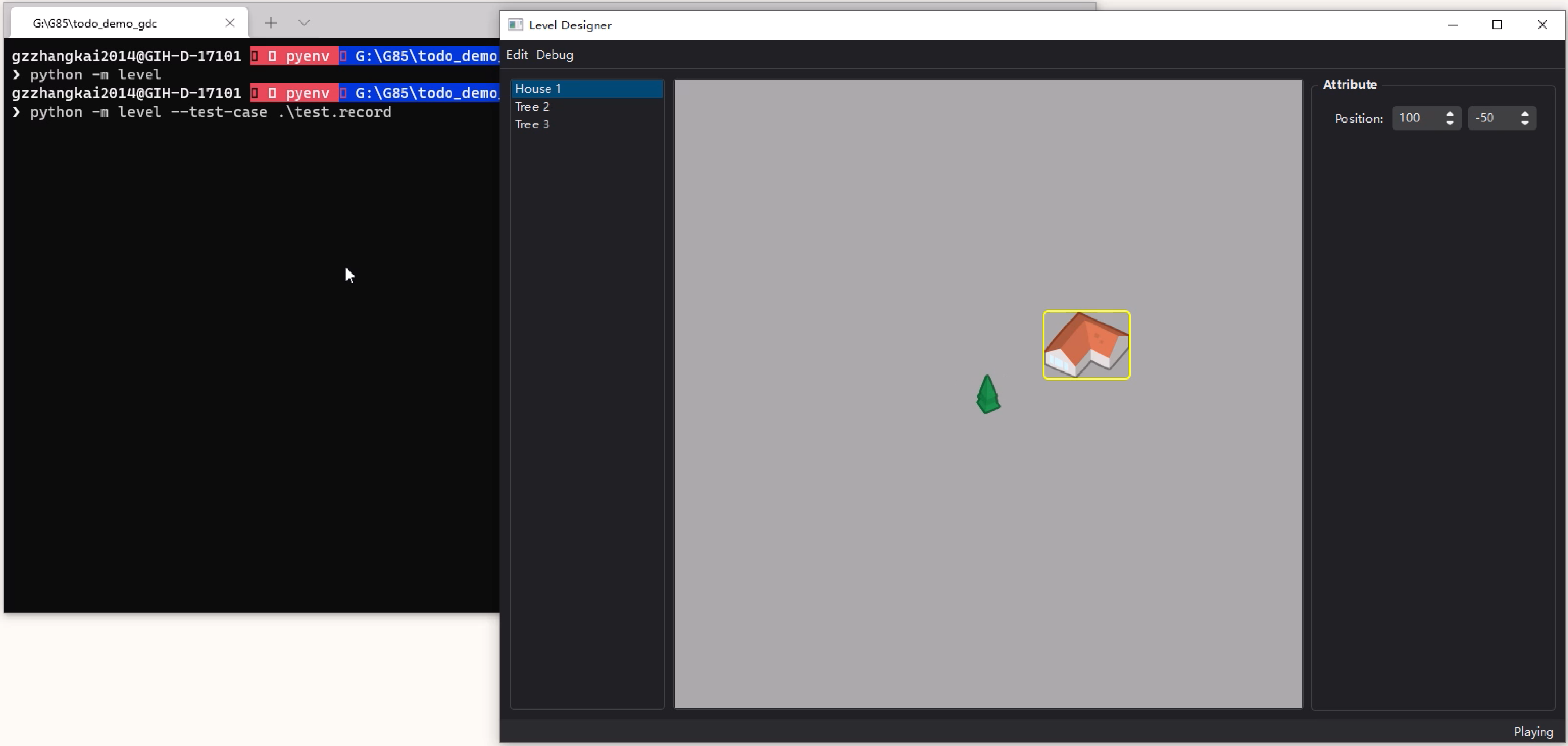
Decouple UI update with data update

- Game object loading
- UI animation
- Expensive data operation on another thread
- Auto save on another thread

AUTO TEST

Data operations → unittest

View logics → ?



```
G:\G85\todo_demo_gdc
gzzhangkai2014@GIH-D-17101   pyenv  G:\G85\todo_demo_
❯ python -m level
gzzhangkai2014@GIH-D-17101   pyenv  G:\G85\todo_demo_
❯ python -m level --test-case .\test.record
```

GOAL

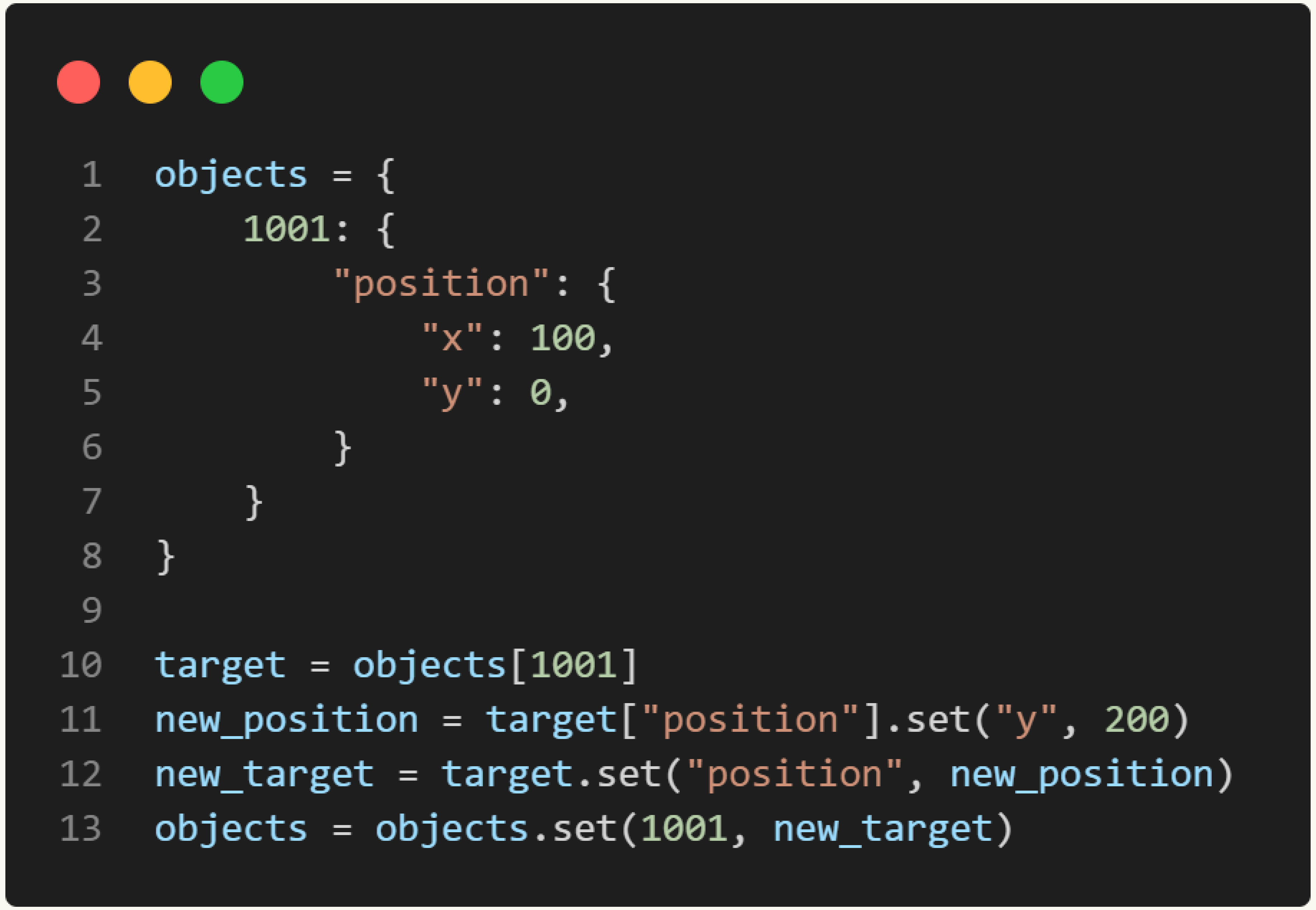
- Increase editor stability
- Increase editor development efficiency
  - Provide a simple undo/redo solution
- Paradigm for all editors
- Fast (enough) performance

MODIFY IMMUTABLE DATA

Transformation

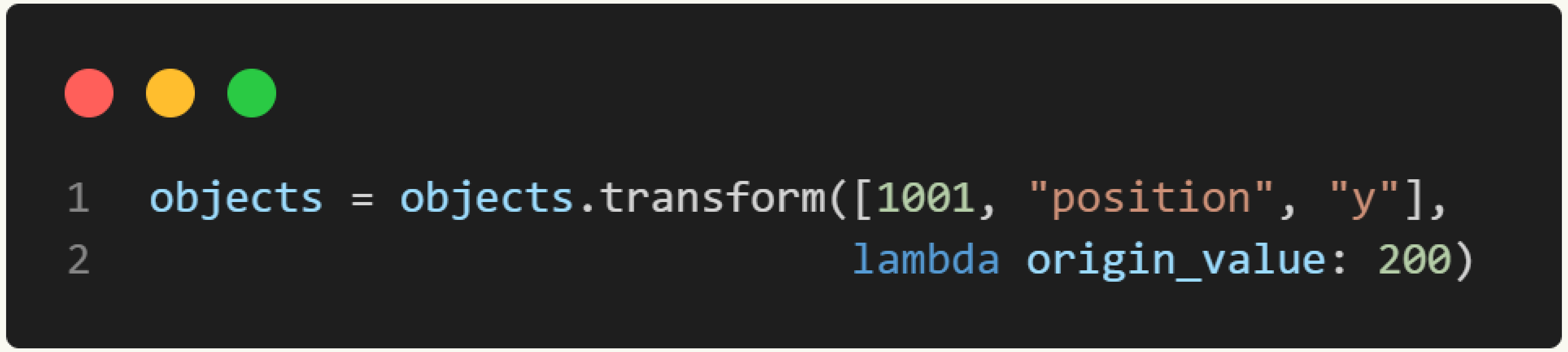
Evolver

TRANSFORMATION



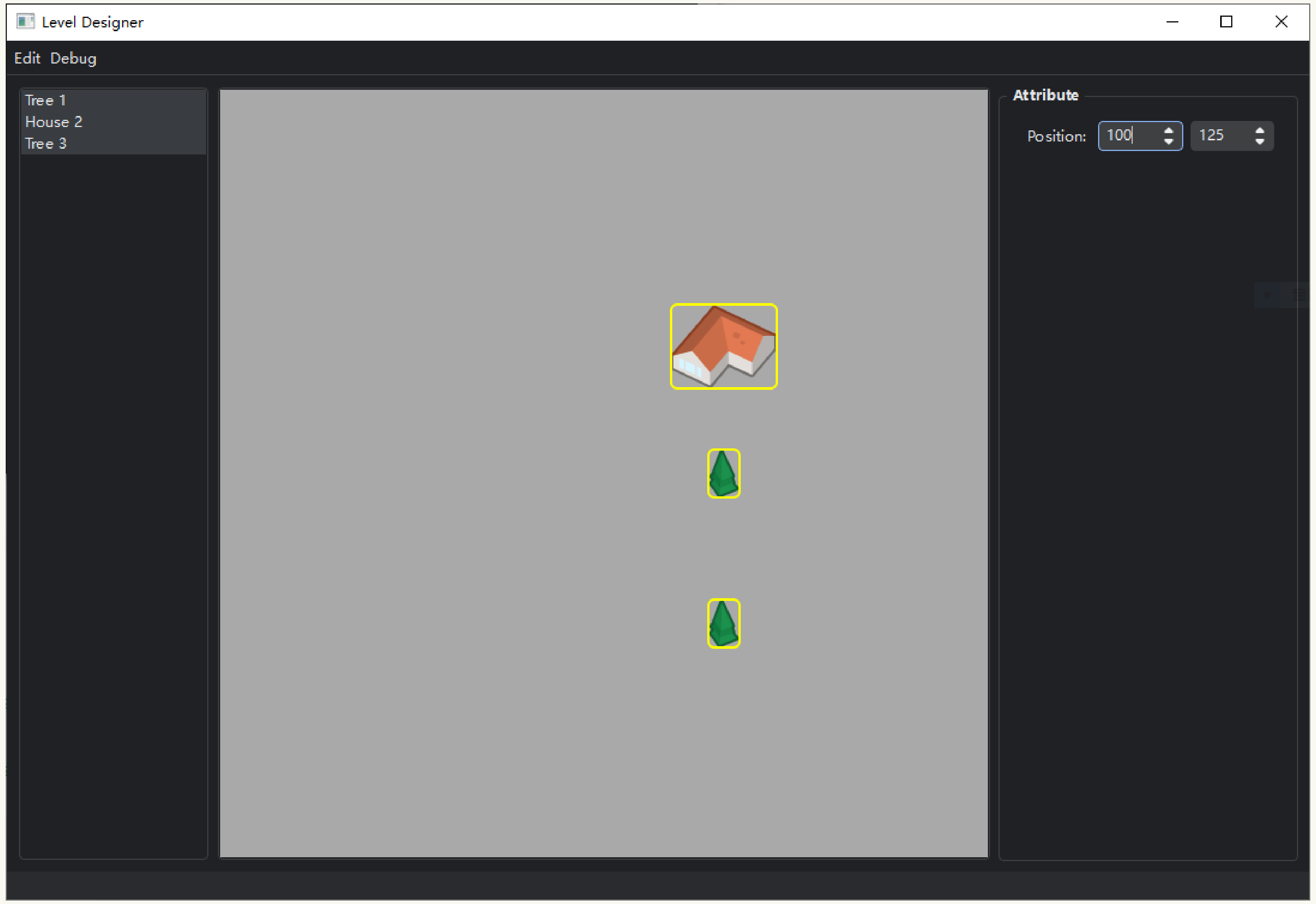
```
objects = {
    1001: {
        "position": {
            "x": 100,
            "y": 0,
        }
    }
}

target = objects[1001]
new_position = target["position"].set("y", 200)
new_target = target.set("position", new_position)
objects = objects.set(1001, new_target)
```

TRANSFORMATION

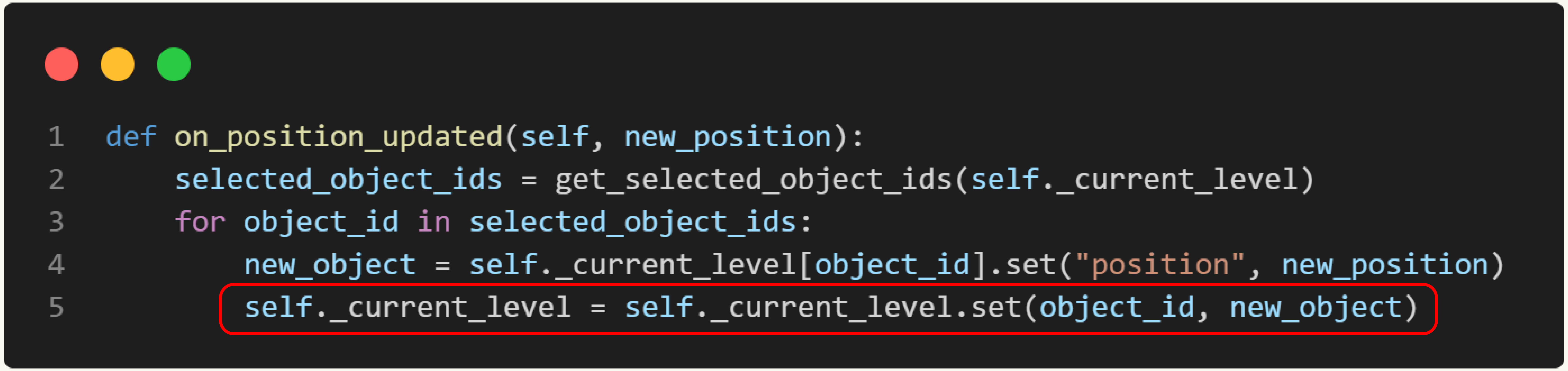


```python
objects = objects.transform([1001, "position", "y"],
                            lambda origin_value: 200)
```

EVOLVER

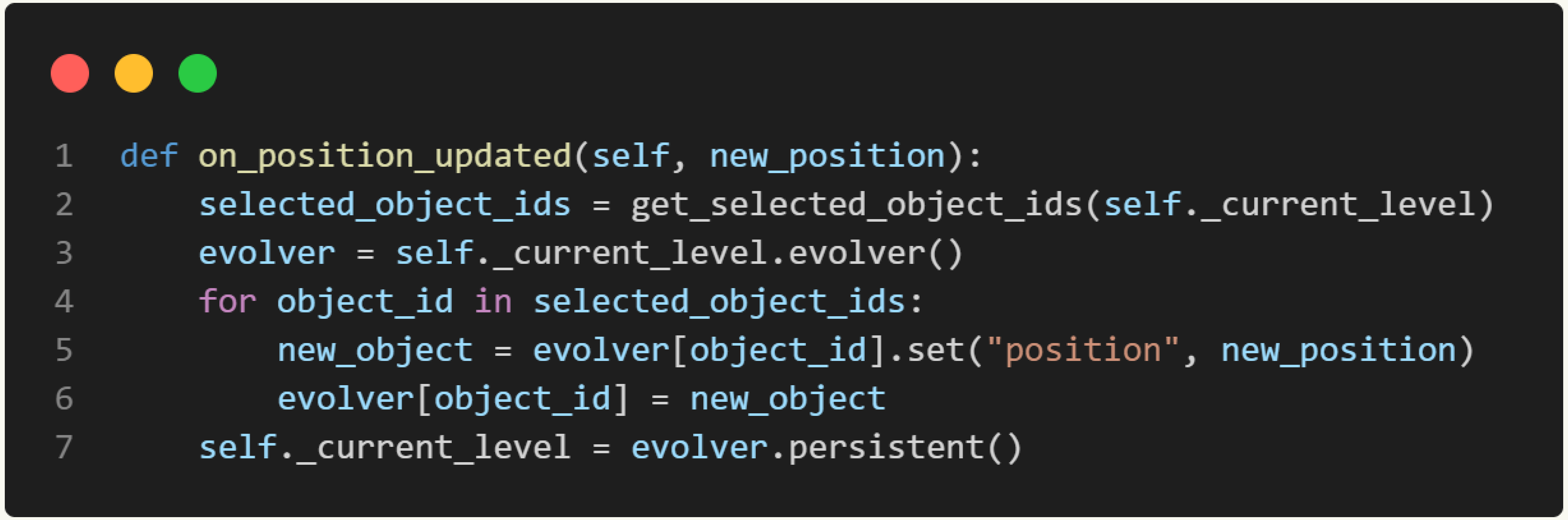

Level Designer
Edit Debug
Tree 1
House 2
Tree 3
Attribute
Position: 100 125

EVOLVER



```python
def on_position_updated(self, new_position):
    selected_object_ids = get_selected_object_ids(self._current_level)
    for object_id in selected_object_ids:
        new_object = self._current_level[object_id].set("position", new_position)
        self._current_level = self._current_level.set(object_id, new_object)
```

EVOLVER

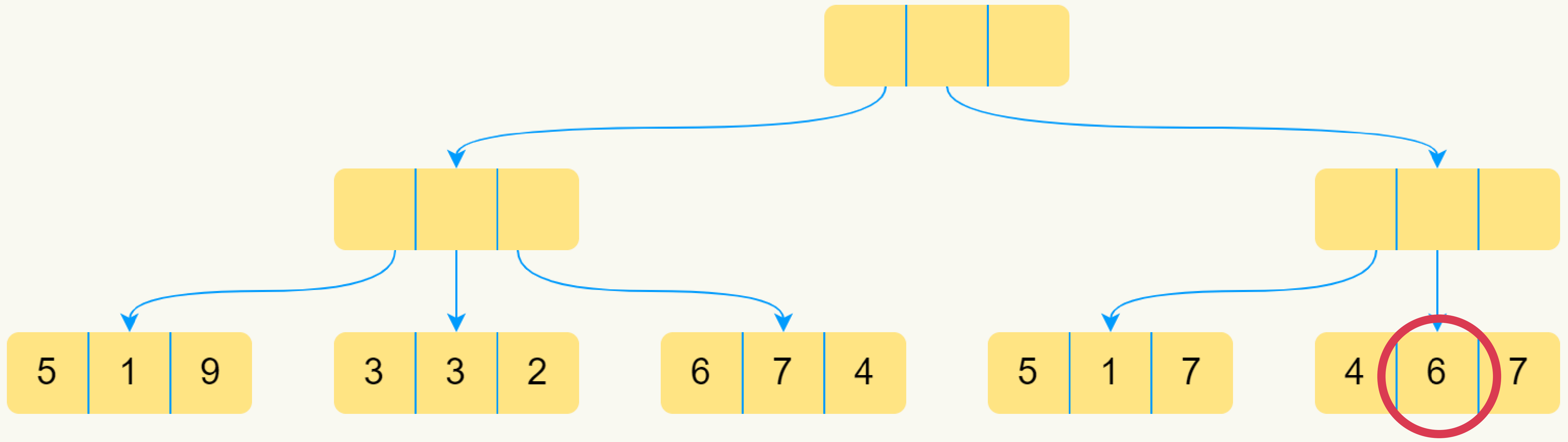


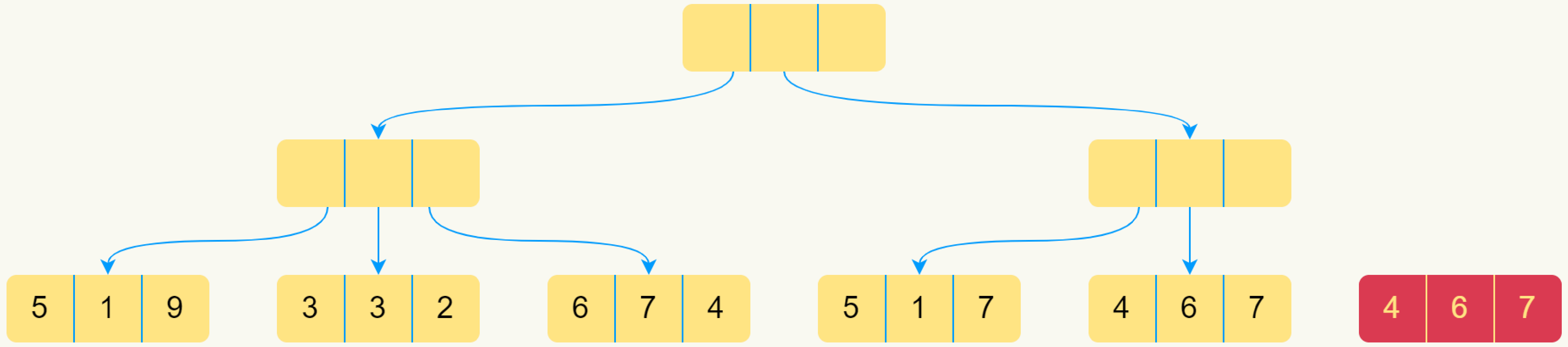
```python
def on_position_updated(self, new_position):
    selected_object_ids = get_selected_object_ids(self._current_level)
    evolver = self._current_level.evolver()
    for object_id in selected_object_ids:
        new_object = evolver[object_id].set("position", new_position)
        evolver[object_id] = new_object
    self._current_level = evolver.persistent()
```

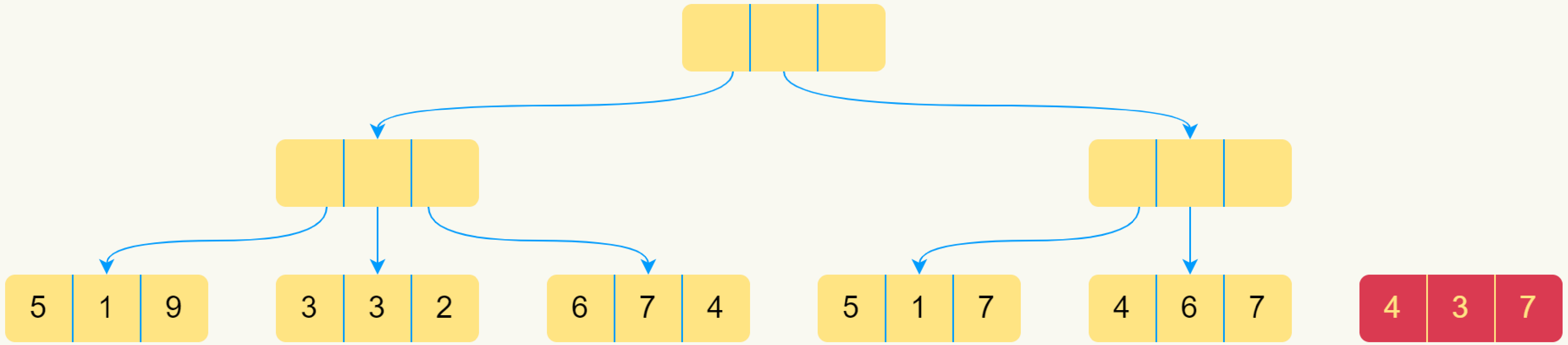
IMMUTABLE DATA

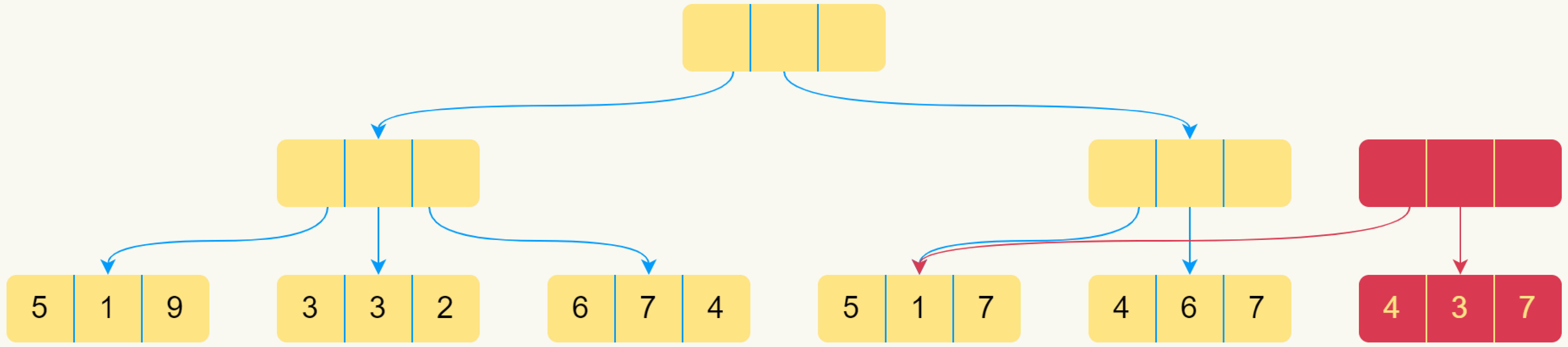
By Rich Hichkey in Clojure

Hash Array Mapped Trie by Phil Begwell

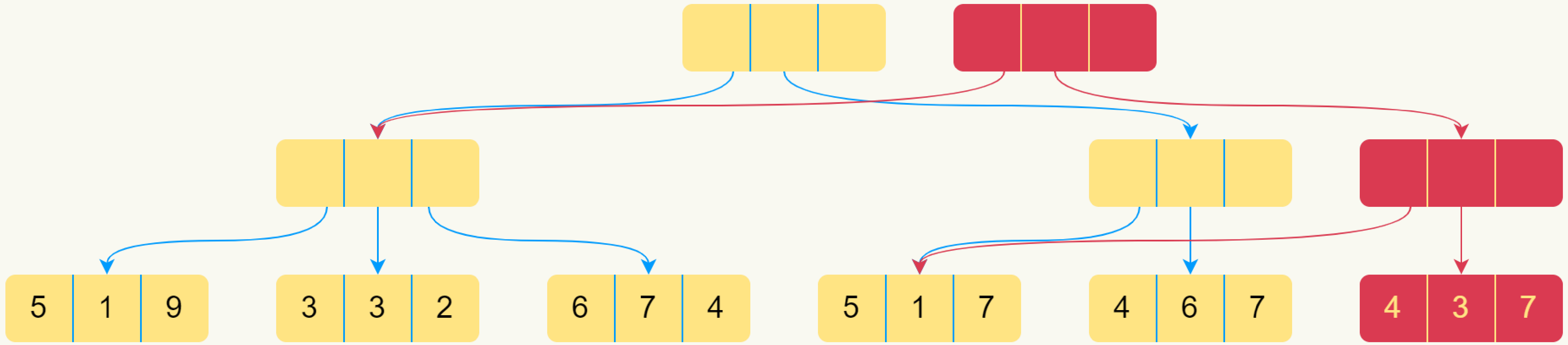

5 1 9
3 3 2
6 7 4
5 1 7
4 6 7


5 1 9
3 3 2
6 7 4
5 1 7
4 6 7
4 6 7


5 1 9
3 3 2
6 7 4
5 1 7
4 6 7
4 3 7


5 1 9
3 3 2
6 7 4
5 1 7
4 6 7
4 3 7

structural sharing



LIBRARY

C++

- Immer

  https://github.com/arximboldi/immer

  CppCon'17 Talk: Postmodern Immutable Data Structures

Python

- Pyrsistent

  https://github.com/tobgu/pyrsistent

- Immutables

  https://github.com/MagicStack/immutables

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THANKS

@kkpattern

https://github.com/kkpattern/immu_editor_gdc