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Exercise Sheet 4 – Solution

Software Architecture for Distributed Embedded Systems, WS 2021/22

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Exercise 4.1: Behavioral Patterns: Observer

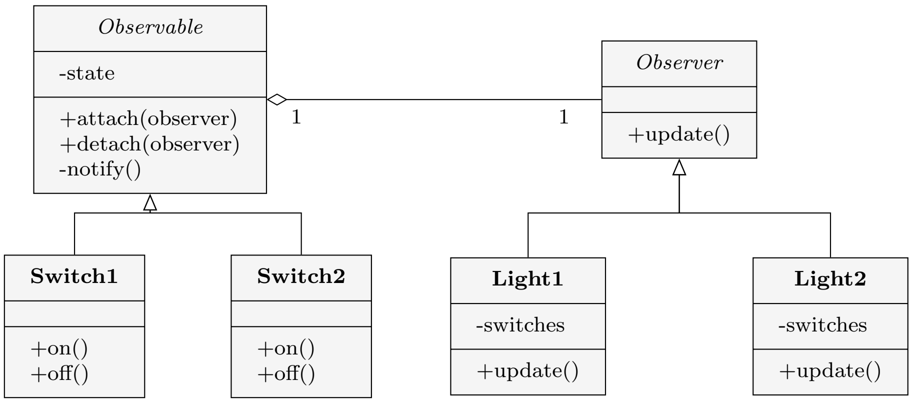
1. We want to model the *AwesomeLights* scenario with the Observer pattern. Assuming the two classes `Switch`, `Light`, which class is the indepentent subject and which is the dependent observer?

Solution:

- Switch: independent subject (user trigger switch).
- Light: dependent observer (lights observe the switch state)

2. Draw the UML diagram for the light and switch scenario using the observer pattern. Assume two lights and two switches. Use the classes `Observerable` and `Observer`.

Solution:



3. Implement the observer pattern in the following code. Remove the class `Controller` and implement the classes `Observerable` and `Observer` (see Moodle for full file).

```
class Switchable():
    def on(self):
    def off(self):

class Light(Switchable):

class Switch(Switchable):

class Controller(threading.Thread):
    def __init__(self, switches):
```

```python
        self.switches = []+switches # expert question: why []+ ?
        self.light_map = [ [] ]*len(switches)

    def set_lights_for_switch(self, switch, lights):
        ...

    def run(self):
        while True:
            for switch_idx, lights in enumerate(self.light_map):
                if self.switches[switch_idx].was_switched():
                    for light in lights:
                        if light.is_on():
                            light.off()
                        else:
                            light.on()

# create lights
l1 = Light("Kitchen")
l2 = Light("Living Room")
l3 = Light("Bedroom")

# create buttons
s1 = Switch("Door")
s2 = Switch("Window")
s3 = Switch("Desk")


ctrl = Controller( [s1, s2, s3] )

ctrl.set_lights_for_switch( s1, [l1] )
ctrl.set_lights_for_switch( s2, [l1, l2] )
ctrl.set_lights_for_switch( s3, [l2, l3] )

ctrl.start()  # start thread
```

Solution:

```python
class Observable():
    def __init__(self):
        self.obeservers = []

    def attach( self, observer ):
        self.obeservers.append( observer )

    def detach( self, observer ):
        self.obeservers.remove( observer )

    def notify( self, msg ):
        for observer in self.obeservers:
            observer.update( msg )


class Observer():
    def update(self, msg): raise NotImplementedError


class Light(Switchable, Observer):
    def update(self, msg):
        if msg == "ON": self.on()
        if msg == "OFF": self.off()


class Switch(Switchable, Observable):
    def on(self):   self.notify("ON")
```

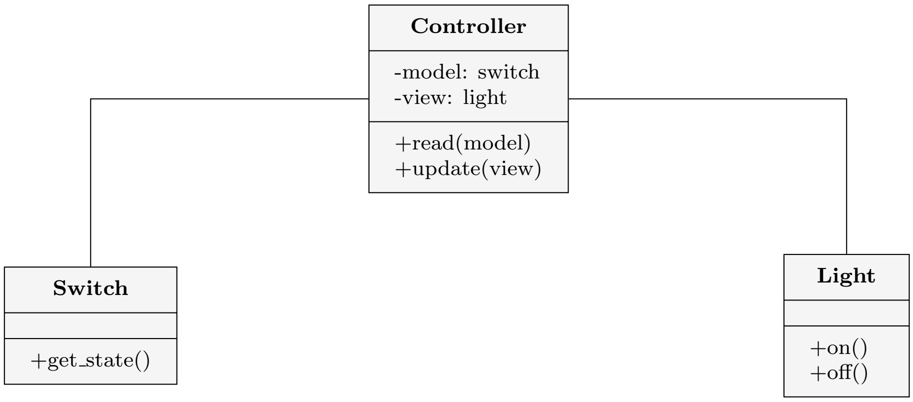
```python
    def off(self):  self.notify("OFF")

....

# attach observer
s1.attach( l1 )
s2.attach( l1 ); s2.attach( l2 )
s3.attach( l2 ); s3.attach( l3 )
```

4. Is it possible to model the *AwesomeLights* scenario with the Model-View-Controller pattern? If yes, draw the UML diagram. If no, explain why it is impossible.

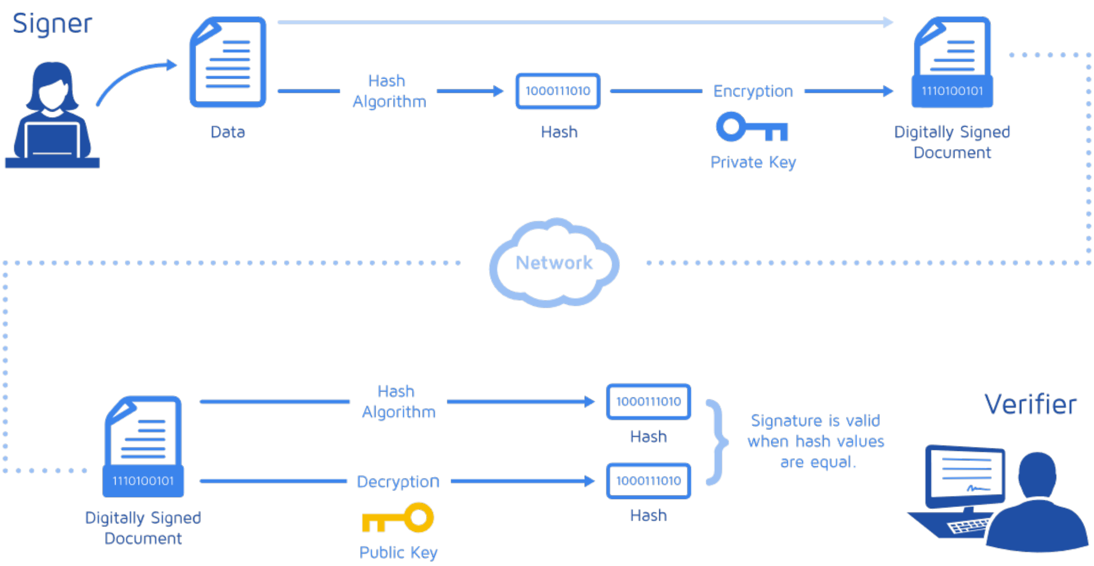
Solution: It is possible. The view is the light and the switches are the model. The controller is the network interface between these two.



Exercise 4.2: Behavioral Patterns: Strategy

From the ESI lecture "System Design for the Internet of Things" you have learned that security is often underestimated in IoT systems. You want to do it better and use Public Key Cryptography (PKC) in order to authenticate the messages between switches and ligths. Since you do not know which algorithm would best fit for a given setup, you decide to support `RSA`, `ECDSA`, and `XMSS` using the **strategy pattern**.

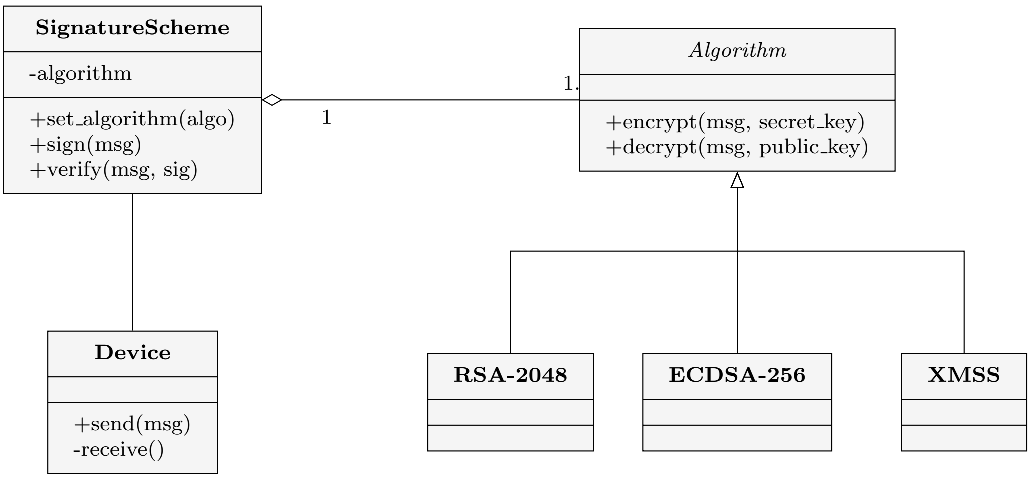
Signing the message works by calculating the hash of the message and then encrypting the hash using the secret key. Any receiver of the message can now "decrypt" the signature and compare it against the original message hash.



https://medium.com/@meruja/digital-signature-generation-75cc63b7e1b4

1. Draw an UML diagram for the three schemes `RSA`, `ECDSA`, and `XMSS` using the strategy pattern. Create the class `SignatureScheme` which provides the functions `set_algorithm(algo)`, `sign(msg)`, and `verify(msg, sig)` and the class `Algorithm` with the functions `encrypt(msg, secret_key)` and `decrypt(msg, public_key)`.

Solution:



2. The following code provides cryptographic functions to authenticate messages with a signature. Improve the code with the strategy pattern to support all three algorithms in a unified way. Implement the class `Algorithm` that provides the functions `encrypt` and `decrypt` (see Moodle for full file).

```
class RSA():
    def encrypt(self, msg, secret_key): ...
    def decrypt(self, msg, public_key): ...

class ECDSA(): ...
class XMSS():  ...
```

```python

# main
msg = "hello␣world!"
secret_key = 42
public_key = 21

ecdsa = ECDSA()

# Sender: signing
msg_hash = calc_hash( msg )
sig = ecdsa.encrypt(msg_hash, secret_key)

# sending msg + sig to receiver ...

# Receiver: verifying
msg_hash = calc_hash( msg )
signed_hash = ecdsa.decrypt(sig, public_key)
is_valid = (signed_hash == msg_hash)
```

Solution:

```python
class Algorithm():
    def encrypt(self, msg, secret_key):  raise NotImplementedError
    def decrypt(self, msg, public_key):  raise NotImplementedError

class RSA(Algorithm):   ...
class ECDSA(Algorithm): ...
class XMSS(Algorithm):  ...

class SignatureScheme():
    def __init__(self):
        self.algo = None
        self.sk = 42
        self.pk = 21

    def set_algorithm( self, algo ):
        self.algo = algo

    def sign(self, msg):
        msg_hash = calc_hash( msg )
        return self.algo.encrypt(msg_hash, self.sk)

    def verify(self, msg, sig):
        msg_hash = calc_hash( msg )
        return msg_hash == self.algo.decrypt(sig, self.pk)

# main
msg = "hello␣world!"

crypto = SignatureScheme()
crypto.set_algorithm( ECDSA() )

sig = crypto.sign(msg)
is_valid = crypto.verify(msg, sig)
```