Programming Project

HotTargui

Contents

1 Introduction

As this is an academic report its focus is more on the learning objectives and process of development than on the finished project. For this reason the report may contain sections praising one approach, only to change it in the next section. In other words the report is an ongoing process, and conclusions drawn in previous sections may not be changes as the report progresses.

2 Distribution of labour

This report has been written as a joined effort between the three participants, yet with the individual parts of the report and code primarily written as defined below. The documentation is proof-read by all members of the group and suggestions and corrections have been incorporated in the affected sections. The below should therefore be considered to be the people responsible for the major part of the work, and does not indicate sole responsibility.

- AlphaTargui (version 1 – only in fist version of report)
  - CRC cards and test lists written at first seminar by all three participants.
  - Class diagrams, sequence diagrams and Software Quality Attributes written by Elund.
  - AlphaTargui implementation written by Anders.
- AlphaTargui (version 2)
  - CRC cards and test lists written at first seminar by all three participants.
  - TDD process documentation and code written by Anders.
- BetaTargui
  - Systematic test, process documentation and code written by Elund.
- DeltaTargui
  - Process documentation and code written by Kewin.
- SemiTargui
  - Process documentation and code written by Anders.
- Assignment 4B (architectural prototype of network enabling HotTargui)
  - Peer-to-peer architecture written by Anders.

- Domain server architecture written by Elund.
- Hosted domain architecture written by Kewin.

- Conclusion written remotely by all three participants.

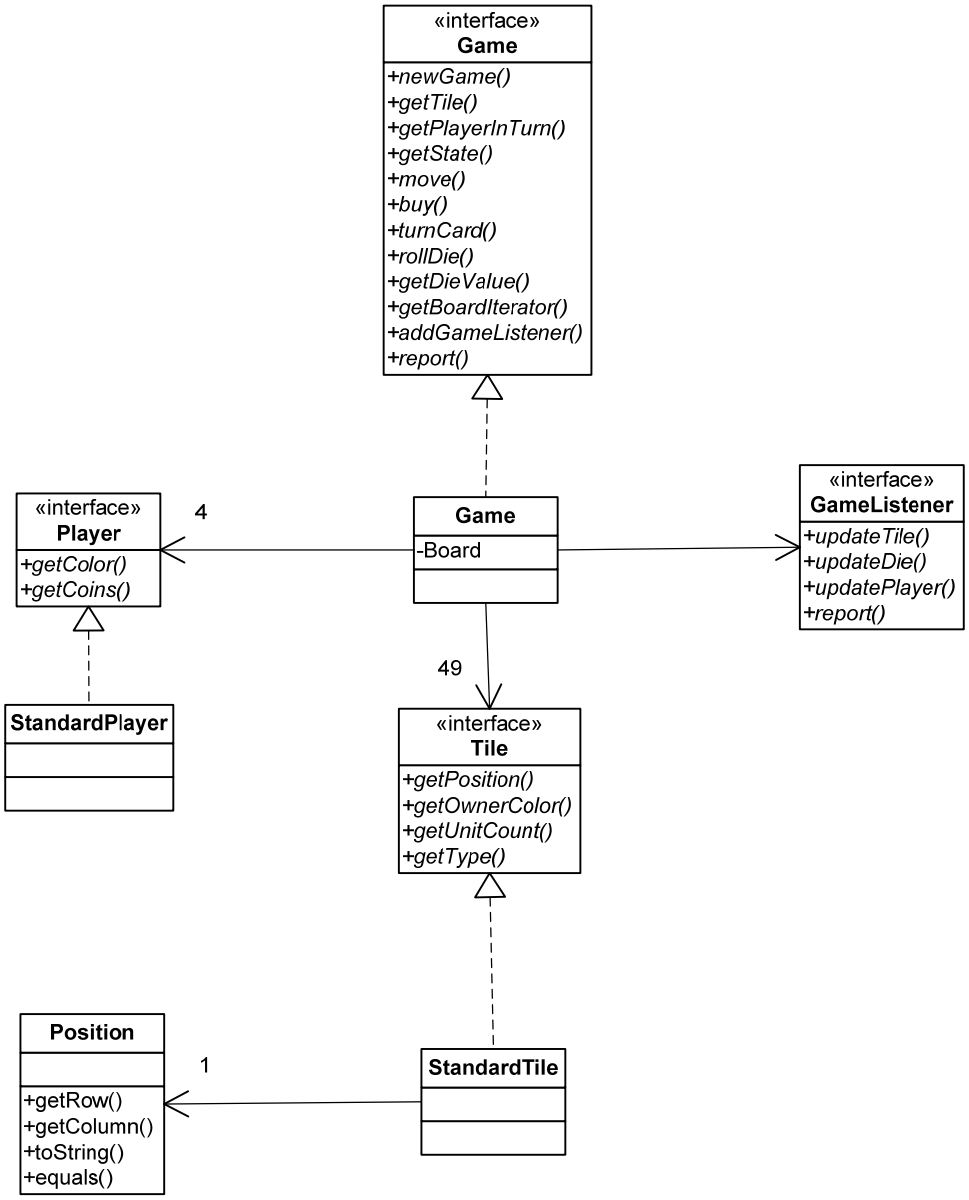
3 AlphaTargui

This product was begun at the first seminar, where we had to determine not only what to produce, but also how to break down the project into manageable pieces and figure out how to work geographically separated.

Test Driven Development is a very quick-decision process, and it is therefore exceptionally difficult to do when the development is performed not only separated in space, but also in time. For this reason we decided to use our time together to define the responsibilities of the different modules of the product, based on the framework handed out and our understanding of what needs to be implemented.

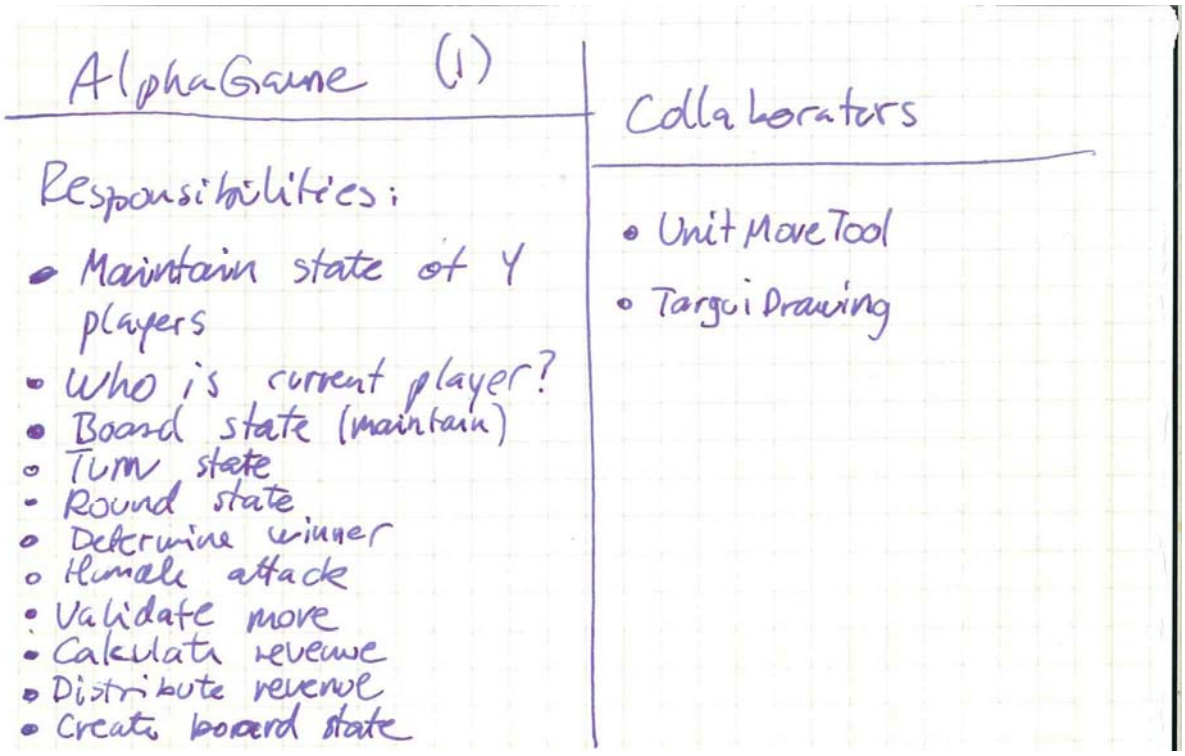
Defining responsibilities may be done in many different ways, yet as we have learned in the course "*Programming of Large Object-Oriented Systems*" it is beneficial to focus on roles, responsibilities and behaviour rather than data, which may be achieved using CRC-cards, so this is what we did. In order to determine the different interfaces/classes involved in the framework and their dependencies, we wrote a quick class diagram of the framework, which was later transcribed to electronic form to preserve it, yet for use with the CRC-cards it was simply a hand-written sketch.

3.1 Initial class diagram

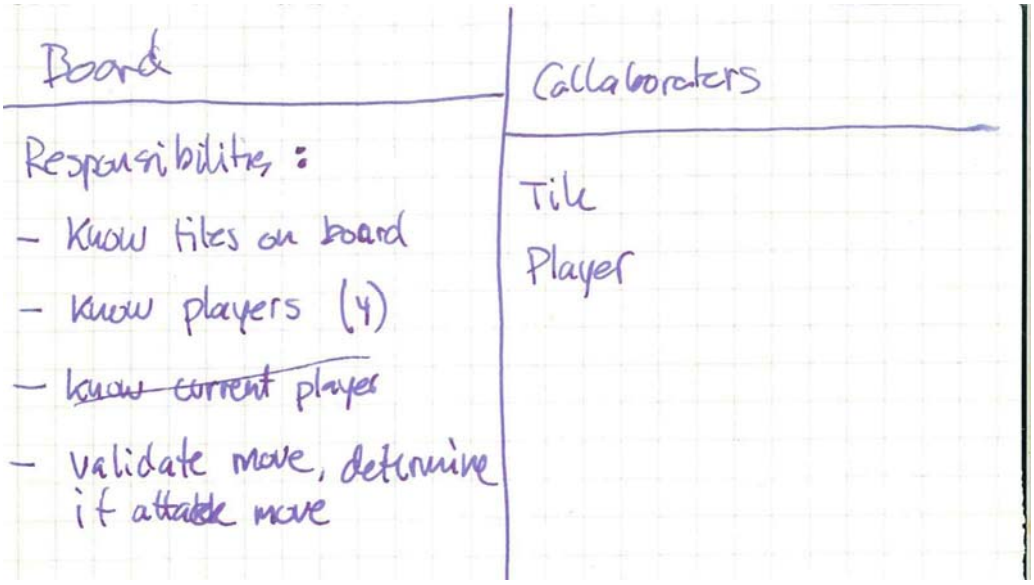


3.2 CRC-cards

We first defined the AlphaGame's responsibilities, yet quickly determined that it had way too many responsibilities and would quickly become “the blob”.



For this treason we decided to split the *Game* implementation into two; one focusing on the static behaviour (the board), and one focusing on the dynamic behaviour (the *Game*). This resulted in the following responsibility for the *Board*.

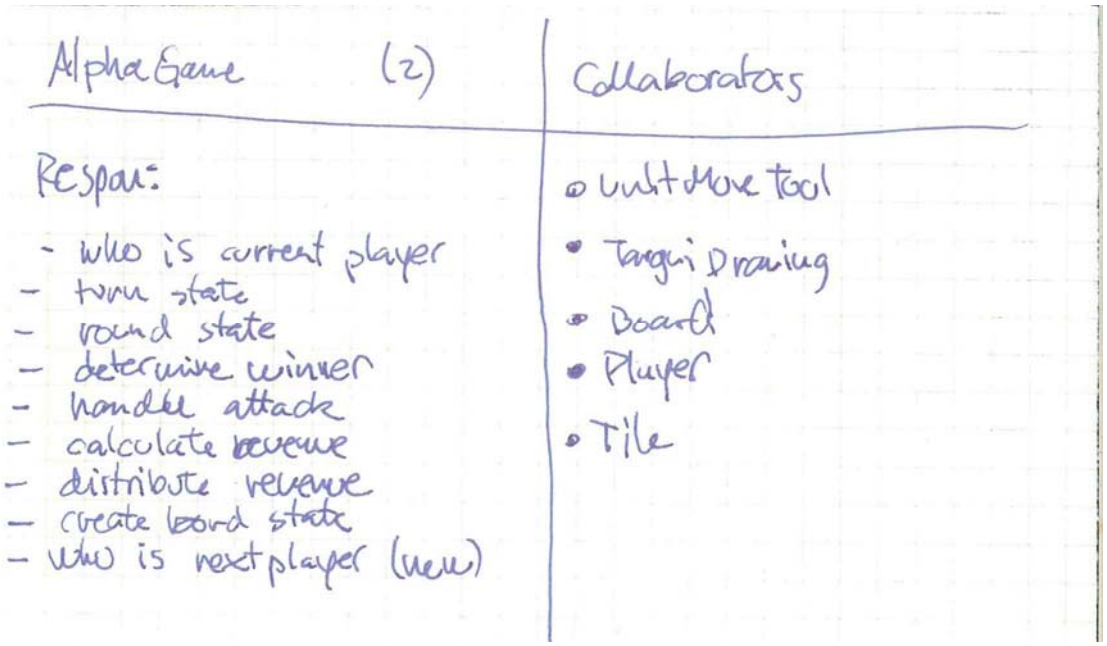


As it may be seen some of the responsibility has been moved to the *Board*.

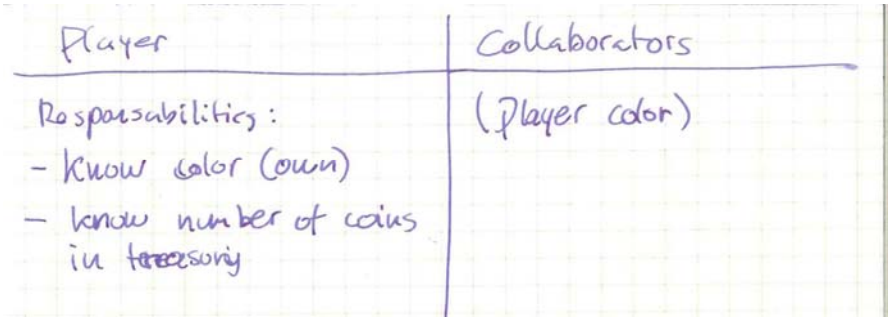
a. State of the board → Delegated to "*Board*".

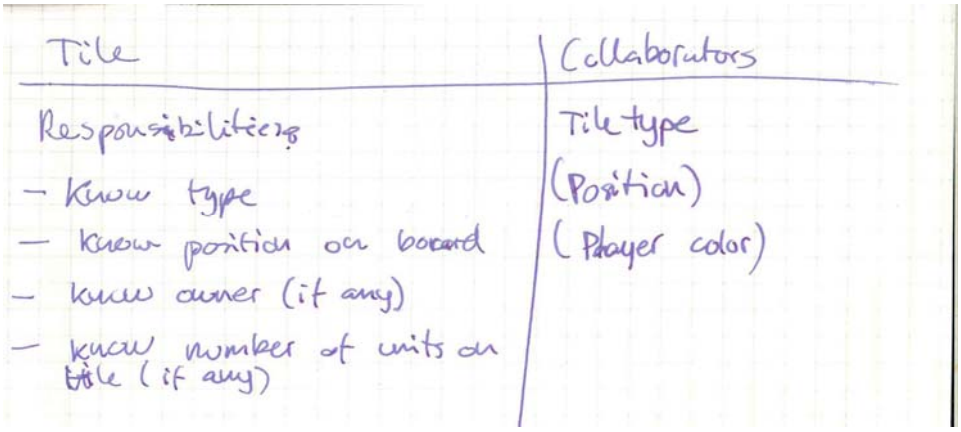
b. Validate move → Delegated to "*Board*" (has knowledge of tiles and players, can determine if move is valid).

This changes the *AlphaGame* class implementation to



The remaining interfaces have not been altered, and we only defined them in order to ensure that no responsibility was forgotten.





Before beginning the actual development process, we also discussed quality attributes and it was determined that there are many important quality attributes, yet when we look at the AlphaTargui game by itself, with no GUI support and no knowledge of products to

come, there is actually only one quality attribute of any real importance, and that is testability, which fits well with the test driven development. Furthermore, as we all know, servicing the testability quality attribute means programming to an interface, in order to allow unit testing where dependent units are stubbed away. It also means opening up some of the state information of the class for testing, which might otherwise have been hidden. This means walking that fine line between testability and information hiding, for even though we focus on testability, this does not mean simply opening up all private data to external modification. We have to remember that the design/framework may have to be used by others, and if a private member can be modified, someone is bound to modify it, even if it is not suppose too and no matter how many doxygen warnings are written to this affect.

As with all test it is important to know the requirements, as they are the bases of the tests. Test Driven Development specifies that it is a good idea to begin with an overall test-list, which simply states the areas that needs to be tested.

We did this also in plenum and came up with a test-list which may be a little more detailed than is the initial intention of TDD, yet as we are to perform the TDD as a distributed effort it helped to ensure a more unilateral approach. This also showed the first ambiguity, as we discovered that we could not determine if it was required to own the settlement that was originally allocated to the player, or if it was enough to simply own a settlement.

3.3 Test-list

- *Player* count. (4)
- *Tile* positions matches specification.
- Round (red first, green second, blue third, yellow fourth, red first).
- Turn (expect move first, expect buy second).
- Move
    - Valid: Move to unoccupied tile.
    - Valid: Move to occupied tile where there are no camels.
    - Valid: Move to each of the tile types with no camels.
    - Invalid: Move with other player camels.
    - Invalid: Move without camels.
    - Invalid: Move to the “Salt Lake”.
    - Invalid: Move outside the board (cannot be tested as the GUI is unable to make this move. Preconditions should be noted, so this test can be avoided).

- Invalid: Move more than one tile in a turn (tested during test of Turn)
- Attack: Attacker has fewer camels than defender (attacker is defeated).
- Attack: Attacker and defender have equal numbers of camels (status quo).
- Attack: Attacker has more camels than defender (defender is defeated).

- Revenues
  - Calculate revenue for all players.
  - Calculate revenue, where one or more players have died.
  - Calculate revenue, where one or more players have lost own settlement.
  - Sums revenue correctly.

  Assumptions: We assume that having a settlement is enough to get revenue compared to having own settlement.

- Determine winner: Play 25 rounds, one must own “Salt Mine”, determine winner.

After writing the overall test-list we went our separate ways, and the following parts of the AlphaTargui was written by individual contributions.

3.4 Test-driven development

Before beginning the actual TDD we had a look at the existing implementations of *Tile* and *Player*, and it was determined that they may be used as-is; at least until a situation arise where it is no longer beneficial – there is no reason to re-invent the wheel.

The existing interfaces (*Tile*, *Player*, *Game* and the value-types they need) will be preserved as much as possible. This is based on the belief that the interfaces was designed for a reason and not simply thrown together. The value types, e.g. *Position*, are believed so simple, and already validated, that they are used without further testing.

Test Driven Development is designed to follow a rhythm with five overall stages; add test; see that the new test fail, but not the previous; make a little change; see that all the test now succeed; refactor to ensure good code.

This rhythm will naturally also be followed in this project, though as it may be seen the small changes can result in extensive refactoring in order to ensure good code.

Test Driven Development is also designed on the premise that it is possible to start with any feature and begin the implementation, but it is required that the feature chosen is implemented fully.

We decide to start with the player count. This is part of the static behaviour and is therefore part of the *Board*. Even though it is not required to create an interface to specify the protocol between the *Game* implementation and the *Board*, from a testing point of view it is a very good idea; programming to an interface.

For this reason the *Board* interface is defined and given the static behaviour from the *Game* interface. This may be done one method at a time or all at once. We have decided to let the interface grow.

In order to service the existing GUI implementation it has been decided not to remove the methods from the *Game* interface, yet simply use the *Game* as a Façade *pattern* forwarding all calls of a static nature to the *Board* interface.

As *Board* is an interface it is naturally not testable, but it does not mean we cannot use TDD, as will be shown in the first iteration, as shown below.

3.4.1 Test *Player* Count

1. Add test case *playerCountEqualsFour*
2. Test case fails to compile as there is no such method.
3. Implement the method *getPlayerCount* in the interface.
4. Test case fail (there is no implementation only an interface).
5. Create class *AlphaBoard* and implement method (obvious implementation, simply return 4)
6. Test case succeeds.
7. Refactoring – No refactoring needed

Already here it may be seen that the rhythm is not quite followed, as the implementation phase requires two steps in order to make the tests pass. As the sub-iterations are very small and the focus is never lost, nor is the overview, it is acceptable.

Another important aspect here is actually the test itself. Tests may be both white-box and black-box, and as TDD is an iterative development process it follows that the implementation is known. For this reason it must therefore be decided if the type that is used in the test-cases is the specific type (*AlphaBoard*) or the interface *Board*. It has been decided to ensure a clear interface that the tests shall as default know only the interface, and then if a more special access is required, cast the instance as needed. Such casting is not required in the first test-case.

As we have now begun the *Player* access implementation we should finish it, and we therefore continue with accessing the actual Players. We are here faced with a decision; should the *Board* know anything about the ordering of the players? (The order in which they play their turns.) This is a very good question. It would be very easy for the *Board* to simply apply significance to the ordering in which it returns the Players, yet this is an

issue of responsibility-creep, where extra responsibility creeps in without is being actively chosen. The CRC-cards says nothing about the *Board* knowing whose turn it is or the order of turns – that is dynamic behaviour.

For this reason the interface is created to be independent of the ordering, and the user of the *Board* must request the player of interest. It is here important to note that a potential problem is discovered; what if a player is dead? Should null be returned, is an isAlive method required? Etc. This is a not an issue we wish to address now, but at the same time it must be remembered, and a test getDeadPlayerFails is added to the test-list for later implementation (and potential name updating).

3.4.2 Iterate Players on board

1. Create test *redPlayerExistInGame*.
2. Test case fails to compile as there is no such method.
3. Implement the method *getPlayer(PlayerColor)* in the interface and in the class (Fake-it, simply return Dummy *Player* no matter what).
4. Test case succeeds.
5. Refactoring – No refactoring required.

This test case naturally do not test that the *Player* returned is correct, so we add another test case.

1. Create test *redPlayerHasRedPlayerColour*.
2. Test case fails.
3. Update the method to return a *StandardPlayer(PlayerColor.Red)* – also a Fake-it implementation.
4. Test case succeeds.
5. Refactoring – No refactoring required.

We still have a fake-it implementation so obviously we are not done. We therefore add the method *greenPlayerHasGreenPlayerColour*, as the *greenPlayerExists* is indirectly tested in this and do not give anything new.

1. Create test *greenPlayerHasGreenPlayerColour*.
2. Test case fails (returns same *Player* as for Red)
3. We are now faced with the option of using the parametric approach and simply introduce an “if”. This is a quick and easily implementable solution, yet it also has some disadvantages. It does not grow well, it opens up for a potential switch-creep (or if-creep in this case) and as the Java framework introduces a much

more elegant solution and it is chosen here. A *Dictionary<PlayerColor, Player>* will allow us to perform a fast and type-safe (due to the generics) look-up. The Dictionary is default filled with four *StandardPlayer*s with matching Key and *PlayerColor*.

4. Test cases succeed.

5. Refactoring 1. Firstly there is a potential for error, as we have a hard-coded player's count (4), and a dictionary containing 4 entries, but what if they came out of sync. We therefore change the *getPlayersCount* to return the number of elements in the dictionary.

6. Test cases still succeed.

7. Refactoring 2. Here we hit our first big refactoring, as we have a problem. The *Board* implementation, according to the CRC-cards, is supposed to know the current set-up of the board, not create the players. This is an example of responsibility-creep, where extra responsibility creeps in without is being actively chosen. There are two options here; supplying the Players in the constructor or implement the Abstract Factory-pattern. This first is most definitely the simplest, and as we presently do not ”know” that there will be other ”creation” required it is sufficient. Moving creation away from the class itself is also a good idea from a testing point of view, as we may now replace the *Player* implementation with a Mock object. In the present test this was not necessary, as we do not need to stimulate any indirect input (*PlayerColor*) in ways we cannot do with the *StandardPlayer*. From a pure Unit-testing point of view we should naturally stub away all functionality other than the UUT, yet we must weigh the advantages and disadvantages. The *StandardPlayer* is a relatively simple implementation, and it is part of the framework, so we can be fairly certain it has been tested and by simply code-inspection convince ourselves that it is correct. The risk of introducing defects in the stub is simply greater, and it is therefore not in the interest of the test to create a stub. The test is supposed to find defects, not service the unit-testing theorem to the letter.

8. Test cases still succeed.

We now implement the remaining tests methods for testing the blue and yellow, as well as test cases for the amount of money initially had (10 as was told at last seminar, as it is missing in specification). These are not shown here as they are of no academic interest. Even though these tests are not made directly with systematic testing, it is still used, as we test all possible elements in a set, and as it is not possible to test anything outside of the set (outside the enum) it is naturally not tested. Even the value 10 is in a way a systematic test, as it is equivalent to any other positive value up to int.MAX. It is not possible to enter a value larger than int.MAX, and negative numbers are simply not allowed (we see this when attempting to buy more camels than we have money).

After implementing the *Player* section we move on to the *Tile* section, and implement the tiles, beginning with the following iteration. The reason for this is not because it has to be that way – we could have chosen any functionality to implement, but we chose to implement the static functionality first, followed by the dynamic.

3.4.3 Iterate tiles on board

1. Create test *iterateTilesCountEqualsSevenTimesSeven*.
2. Test case fails to compile as there is no such method.
3. Implement the method *getBoardIterator* in the interface and in the class (Fake-it, simply return a 49 *Tile* dummy iterator).
4. Test case succeeds.
5. Refactoring – Already here we can see that we are faced with the same problem as we were with the *Player*; the *Board* implementation is not suppose to create the Tiles. Again we could choose to supply the tiles in the constructor, yet the constructor is getting rather cluttered, so instead we use the Abstract Factory pattern, and introduce a *BoardFactory* interface which can create not only the required tiles, but also the Players which was previously supplied in the constructor. This is also done in small stages.
    a. Introduce *BoardFactory* interface and method *createPlayers*. Use method to create Players in *AlphaBoard*.
    b. Test cases fail.
    c. Create *AlphaBoardFactory* (Obvious implementation – move code from test constructor to factory. We could have created a BoardFactoryStub for use in the testing, yet it would have to have the same functionality as the real *AlphaBoardFactory*, so it would merely be a waste. Naturally this goes against the rules of Unit-test, as we test more than one unit (both *AlphaBoardFactory* and *AlphaBoard*), yet *AlphaBoardFactory* is deemed as simple as any stub and it is therefore acceptable.
    d. Test cases succeed.
    e. Update *BoardFactory* interface with *createTiles* method, and use it in *AlphaBoard*.
    f. Test cases fail (compile error *AlphaBoardFactory*)
    g. Update *AlphaBoardFactory* with dummy implementation from *AlphaBoard*.
    h. Test cases succeed.

Here it may be seen again that the refactoring becomes more than just removing duplicate code, in order to keep the code good. This is not just a single occurrence. It seems that when using TDD, just like with XP, the rules should be followed judiciously. It is sometimes necessary to think a few steps ahead to avoid major refactoring. This does not mean design everything in advance, but simply that sound judgement also has a place in TDD.

Moving on to the next iteration we could validate the content of a single of the tiles, or we could validate the layout of all tiles. Taking small steps we should create test cases for each tile, like *tiler0c0EqualsSettlement*, *tiler0c0OwnedByRed*, *and tiler0c0Has10Units*. One may argue whether this is beneficial, as it does create a lot of test cases (49*3=147 to be exact). In practice we believe this would never be an advantage, as it is quite possible to handle adding the entire tile-setup in one goes. It is, as can be seen in the code, only a single line per tile. We will however do it properly, and show the first iteration below.

1. Create test *tiler0c0EqualsSettlement*. We here had to decide if Position should start at 0 or 1. There does not have to be a one-to-one between the test name and the code (we could extract position 0,0 even though the name of the test is 1,1), but it is a good idea for readability. Since Position is defined to begin from 0, we decide to also use this.

2. Test case fail (Dummy *Tile* not equal to Settlement)

3. Update *AlphaBoardFactory* to return Settlement for tile 0,0 instead of dummy.

4. Test case succeed

5. Refactoring – Update the *Board*-interface with new method to return a specific *Tile* based on row and column. This saves iteration each time to find the correct *Tile* (at least in the calling code).

The remaining 146 iterations are not shown, as they are simply a matter of doing the above for each tile, and then updating the returned tile to match unit count and owner.

After these test-cases the board should be fully tested for initial static behaviour. Naturally, as the factory is called every time this is a stateless implementation, which is completely useless in a *Game*, but this will not be discovered until the implementation of the dynamic behaviour where the content of the *Board* has to change.

We choose to start with the *Player* ordering first (Red, Green, Blue than Yellow), but first we have to decide if we want to follow the pure unit-test approach and stub away the board (or from a pure TDD point of view, not use it). As the board is pure static functionality stubbing it will introduce a risk of generating new errors far greater than the risk of using the implementation, so this is not wise. We therefore choose to use the *Board* implementation in the *AlphaGame*. How is the *Board* implementation supplied to the *AlphaGame*? Well, to facilitate testability we supply it in the constructor, so it may be stubbed away should the need arise and also allow for replacing the board implementation. For now there is no need for a *GameFactory*.

3.4.4 Player turn ordering

1. Create test *redHasTurnFirst*

2. Unit test fail (null reference exception – *getPlayerInTurn* return null)

3. Fake-it. We implement the *getPlayerInTurn* to simply return *Red* player from *Board*.

4. Test case succeeds.

5. Refactoring – none needed.

Then we want to implement the second player turn, and now we hit a snag. How do we change turns when we have not implemented the die roll, move or buy? Perhaps the turn was not the best suggestion? Is it not possible to choose any test to implement? Of course it is.

1. Create test *greenHasTurnAfterRed*

2. Unit test fail (always return Red).

3. Create fake-it *buy* implementation, which simply changes the current player to green (it is allowed to buy without moving, which ends the turn)

4. Test case succeeds

5. Refactoring – We create method *goToGreenTurn* in order to increase readability.

We follow this approach to *Blue*, where we see an option for refactoring.

1. Create test *blueHasTurnAfterGreen*

2. Unit test fail (return yellow)

3. Here we could simply implement another change, but with our triangulation we can see that the fake-it does not make sense any more. We therefore implement a buffer and an index which is updated every time a buy is processed.

4. Test case succeeds.

5. Refactoring – We create method *goToBlueTurn* in order to increase readability and avoid multiple *buy*s under each other

For *Yellow* it is merely a matter of adding yellow to the buffer so we do not show it here, but for the final one we see a possibility for improvement.

1. Create test *redHasTurnAfterYellow*

2. Unit test fail (index out of bounce exception)

3. Implement resetting of the index when index reaches 4 (turning the buffer into a cyclic buffer). This is also the completion of a round, but it is of no importance now.

4. Test case succeeds.

5. Refactoring – Here we see the risk of switch-creep. We have to manually ensure that the index do not exceed 4. By encapsulating this it makes the code much more readable, and we using a strategy pattern to encapsulate the cyclic buffer. We introduce the *PlayerTurnStrategy* interface and *SimpleTurnStrategy* implementation where we move the implementation of the cyclic buffer too.

6. Test case succeeds.

7. Now of course we have two arguments for our constructor. Is this acceptable? Well, it may be and it may not - it is very much up to the individual. We however decide to create a *GameFactory* interface to create the board and the *PlayerTurnStrategy* and create an *AlphaGameFactory* with the creating code from the test and the *SimpleTurnStrategy*.

8. We move the code for going to red after having been to yellow, or “completing a round” in a method called *completeRound* to increase readability.

For the next iteration we choose the ordering within the turn (move (optional) than buy (may purchase 0)).

3.4.5 Player Turn

Since it is allowed to not move, the buy-buy is allowed, just like move-buy and buy-move. The only illegal option is move-move. Naturally the first command is always valid and is not part of the test case (it is not validated).

1. Create test *buyBuyAllowed*

2. Test case succeeds

The same is true for move-buy and buy-move and we therefore skip them here and move on to move-move. We also realise that as it is not allowed we have to be careful with error hiding. If move incorrectly change to the next player then a following move would of the same players position would be invalid due to error-hiding, and if an incorrect move implementation kept the current player, and simply allowed multiple moves, then it would be error hiding if we moved the next player’s camels. Other errors could occur, and the question is, should we try and predict all the possible move errors. We do not believe so, and choose the most likely, where the move do not change state at all (allow multiple moves on same player)

1. Create test *moveMoveSamePlayerNotAllowed*

2. Test case fails

3. Triangulating with the previous means we cannot simply return false, so we implement a switch-based state pattern where buy always change state to move and move only succeed if state is move and then change to buy. There is a problem here, though. The CRC-cards state that the Board is responsible for move validation, and yet this implementation is in Board. We decide to postpone

the issue until we reach the invalid moves implementation later, and simply make a note of it in our test-list.

4. Test case succeeds.

5. Refactoring – Well, this is a parametric implementation of the state pattern, as oppose to the fully fledged implementation with sub-classes. It is however deemed acceptable here, at least for now.

3.4.6 Move

Here is an interesting difference between systematic testing and TDD, as the breakdown of the tests into valid and invalid moves looks very much like Systematic testing, yet it is important to realise that it is not. These are overall TDD test cases, and we should therefore not attempt to test as many valid situations in one test case as possible. We should instead take small steps and create a single test case for each. In TDD the issue is not an explosion of test-cases – quite the contrary. It may be a little much to claim that more is better in TDD, but it is close. The smaller steps, the better and smaller steps mean more test cases. This is naturally only true to the point where the steps become smaller than what is beneficial, as TDD does advice using common sense when breaking down the overall tests into their individual steps.

This section also present an important possibility, as it will allow for the use of test-stubs. Instead of choosing the *AlphaBoard*, we can choose a *TestBoard* which can be configured to have the setup required. This same situation can be achieved by choosing a different *BoardFactory*, as it is the factory that determines the initial layout. The first is most unit test-like, as it means the least amount of units (only the *AlphaGame*) are parts of the test. Unfortunately it also has some disadvantages, as more functionality has to be introduced in the *Board* interface.

We also have to decide how much we want to test in a single test case; e.g. move 2 camels means validate move and extract two camels from current location, add two camels to destination and update ownership. Based on the “take-small-steps” principle we naturally create test-cases for each situation.

1. Create test *redMoveTwoCamelsFromRedSettlementWithTenCamelsToEmptyUnownedErgValid*

2. Test case succeed – always return true

We could now move on to other valid moves, but that would not make much sense, as they would all succeed. Instead we finish the move to Erg.

1. Create test *redMoveTwoCamelsFromSettlementWithTenCamelsToEmptyUnownedErgGivesOwnershipToRed*

2. Test case fails (the tile moved to does not change the Erg tile)

3. We could now fake it and simply set ownership to Red, but this would go against the test description, as it states an empty unowned Erg. We therefore implement the beginning move facility where it simply updates the tile owner to the owner of from – no matter what. This is true TDD, as we do not consider "what if you move form an unowned tile?" or "what if it is occupied?" etc. we only look at the test. Implementing this gives us a problem. The *Tile* does not have any way of being updated. We could cast it to StandardTile, but that it not very nice, as it results in a hard binding between *AlphaGame* and StandardTile, making it impossible to change the *Tile* implementation, in which case we might as well add the update methods from StandardTile to the *Tile* interface. This is also a solution, yet we do not really want future programmers, and users of the framework to start modifying the Tiles – they are emutable, just like Java strings. Well, how has Java then solved this problem? Well, yet have implemented String so that any methods which modify a string return a new instance of String equal to the modified string. Doing this is of course a creational matter, and not one we have to consider right here, as we have another layer of abstraction – the *Board*. The board may simply present a Façade for the move functionality, and then the actual implementation is done in *AlphaBoard* (see later). We therefore create a new method on the *Board* interface called *updateTileOwnership(Tile t, PlayerColor pc)*. In order for the test case to succeed we have to implement this method. We could implement it in the *TestBoard*, yet the problem is. How different will it be from the actual implementation needed in the *AlphaBoard*? We have to decide if we want to continue using the *TestBoard*, or if we should choose the alternate solution of creating a TestBardFactory and use the real *AlphaBoard*. We choose the latter, as we believe it is more important to avoid duplicate code and thereby duplicate risk of error, than it is to adhere to the Unit-testing principles. This can also be seen from the fact that the *Board* functionality is tested via the *AlphaBoard* test cases. This is due to the fact that we are doing TDD and not unit testing; we believe that they are not the same. For this reason we implement the *updateTileOwnership* method to simply replace all tiles with Red ownership (fake-it), and yet we now have the problem of responsibility again. The *Board* implementation is not supposed to create Tiles; it is only suppose to hold them. How do we fix this? We simply add a *createTile* method on the *BoardFactory* interface which creates a new tile, identical to the previous except with the updated ownership and then have the *Board* implementation call this. This resulted in changes to *AlphaGame*, *Board*, *AlphaBoard*, *BoardFactory* and *AlphaBoardFactory*. Is this a small step? Not really, but there is no easy way around it and it is only small changes in the different locations. Is it good TDD? Good question.

4. Test case succeeds.

5. Refactoring – We can see that in the *AlphaBoardFactory* implementation we have two places where Tiles are created; *createTile* and *createTiles*. We can avoid this by having *createTiles* call *createTile*, and this refactoring is implemented.

We could see from this iteration that it was not possible to keep nice responsibilities and at the same time take small steps (depending of course on the definition of "small"). This seems to be one of the problems with TDD, as it relies very much on a form of unit-

testing, which do not support interdependencies between units very much – just like unit-testing also does not. It may also be due to a poor use of TDD that the situation arose, or to a bad distribution of responsibility, yet whatever the reason, the problem exists and focus is easily lost. With the interface update in place we continue with the remaining test cases for the move, which should hopefully fit better with the TDD rhythm.

1. Create test *redMoveTwoCamelsFromSettlementWithTenCamelsToEmptyUnownedErgResultsInEightCamelsOnSettlement*

2. Test case fail (the from *Tile* is not changed)

3. Update *Board* interface with *updateUnitsOnTile(Tile t, int newCount)* and implement this method (done by using the createTile method from *BoardFactory*). Finally set the *AlphaGame* move to use this command. We could choose to hard-code the number 2, yet as it is an argument directly accessible and nothing is gained by faking it, obvious implementation is used.

4. Test case succeeds.

5. Refactoring – none needed.

Here we again see that the rhythm is not quite as simple. We have to change an interface and two implementations, which may be simple updates, but is still multiple files, and it is easy to lose focus.

1. Create test *redMoveTwoCamelsFromSettlementWithTenCamelsToEmptyUnownedErgResultsInTwoCamelsOnErg*

2. Unit test fails (only from is updated)

3. Call *updateUnitsOnTile* on the *fromTile* and extract the 2 units.

4. Test case succeeds

5. Refactoring – no refactoring needed.

These four test cases showed a valid Red move to Erg. To be completely exhaustive we should test to all player colours and to all valid types of tiles. We do however have an advantage of the white-box knowledge. If we implement the invalid moves as an exclusion algorithm, meaning we test for equality with invalid tiles, then we can put all valid tiles in the same equivalence class and therefore only have to test one. Naturally as the Tiles are a set, they should all be tested according to systematic testing, which is where equivalence classes comes from, so it is slightly contradictory. As it is always the case with Equivalence classes. When in doubt, divide into two, and we should therefore create tests for all the valid Tiles. This is more systematic testing than TDD, though. The same is true for the players, even though it is pretty obvious that the validity-algorithm for empty unowned tiles is not going to be dependent on player colour. These test-cases

are not included in the report, as they do not contribute to the understanding of the process/product and we continue with move onto occupied empty tiles.

1. Create test *redMoveTwoCamelsFromSettlementWithTenCamelsToEmptyYellowErgValid*

2. Unit test succeeds

The big question is – do we want to continue writing tests we know are going to succeed? We should, as they may begin failing when we implement the attack algorithm and yet is there a difference (equivalence class difference) in an unowned *Tile* and an Owned but empty *Tile* from a move point of view. Well, as the rule goes: “If you ask the question then there is a difference”, so we implement the remaining three test cases. These are not included in the report as they have no academic merit. The same goes for testing an owned empty tile of each *TileType*, as this should, from a systematic testing point of view, also be included. This also goes for the from tiles. Is there a difference between moving from a Settlement and moving from an Erg? As this is TDD, and we know the implementation, we have decided to say; no, there is no difference, and for this reason no other valid from tile type is tested.

We now go to the invalid moves, and start with

1. Create test *redMoveTwoCamelsFromSettlementWithTenCamelsToSaltLakeInvalid*

2. Test case fail (we faked it so it simply returned true)

3. Triangulate – we now has to implement the validity-check, and as the CRC cards specify that it is the *Board*'s responsibility to determine validity, we have to update this interface with a method validateMove(Position, Position, PlayerColor) which indicate if the move is valid or not. This may be used directly in the *AlphaGame* implementation. Implementing the *validateMove* is simply return true in all instances except if “to” position point to a Salt lake.

4. Test case succeeds

5. Refactor – no refactoring needed.

1. Create test *redMoveTwoCamelsFromGreenSettlementWithTenCamelsToErgInvalid*

2. Test case fails

3. The validation of move algorithm only looks at Salt Lake, and not at whose turn it is. Unfortunately the *Board* does not know whose turn it is, and can therefore not perform the validation. This is called a responsibility conflict, and we have to decide if we want to teach the *Board* whose turn it is, move all validation to the game, has validation code in both the *Game* and the *Board* or move validation to a separate class. The simplest is naturally to validate the player-turn in the *Game* and leave the rest in the *Board*, but this is not very good design. It is difficult to

understand and maintain. Teaching the board about which turn it is, e.g. by supplying it with a *Game* reference is possible, but also causes a more complex design, as there is now a two-way reference between *Game* and *Board*, and that should be avoided. We can move the validation to the *Game* implementation, but it already have plenty of responsibility, and we do not want “the blob”. We therefore begin a Refactoring using a strategy pattern:

1. Create *MoveValidationStrategy* interface by moving method from *Board*.

2. Update *AlphaGameFactory* to create instance.

3. Update *AlphaGame* to use the factory to create strategy

4. Update *AlphaGame* to use strategy to validate move

5. Create *StandardMoveValidationStrategy* class and move the validation code from the *Board* implementation. We also remember that we found a problem during the move-move test, with some validation code that was left in *Game* (move only in Move state), and move the state validation too. This requires that *StandardMoveValidationStrategy* knows both Board and Game, and that is a problem. Game takes a *GameFactory* reference, so *GameFactory* does not know Game. How do we get a reference to Game inside *GameFactory*? There are several possibilities.

    1. We can move the *GameFactory* out of the Game's constructor, so it can be created first and then use a simple set-method. We look at the code to validate, and it is possible as we have newGame to do all initialization.

    2. We can also set the Game on the *MoveValidationStrategy* after the fact. The key is to make sure it cannot be forgotten - this means not leaving it up to the programmer.

    3. We can implement a publish-subscribe system thereby allowing loose binding eventning of information, but it requires quite a lot of refactoring.

    The disadvantage of set-methods is that they can be forgotten, Set-methods have the disadvantage that they can be forgotten. We believe that it is most likely to be remembered where configuration is done anyway, and that is at the creation of the Factory, and we therefore choose to create a set method on *AlphaGame* and update *AlphaGameFactory* to take Game in its constructor.

6. There is another serious issue. An abstract factory is supposed to create new instances every time, but it is not possible, as the *Board* returned by *createBoard* MUST be the same as is supplied to *StandardMoveValidationStrategy*. Luckily the Game acts as a proxy for the Board and we can avoid supplying the *StandardMoveValidationStrategy* with the Board at all.

7. As we have no systematic testing of the *Board* interface this breaks none of the test-cases, as the test cases test functionality and not interfaces, and that is nice. We then introduce the test of the *Tile* is owned by the *Player* who's turn it is in *StandardMoveValidationStrategy* and return false if not.

4. Test case succeeds.

5. Refactoring – none, as this was done during implementation.

Here we saw a different aspect of the TDD process. What to do when you realize a bad design. Does it follow the rhythm? No, we do not think so, but the focus on functionality in the testing does ensure that the test cases are still valid, which is very nice.

Here it may also be argued, according to systematic testing, that we need to test that the move was not performed anyway. This could be tested by simply also validating that the tiles have not changed, yet as we know the code, we know that the false is returned before any move-code, so it is not possible. Of course saying something is not possible is the same as saying it is going to happen, but this code is so simple we are confident in it. There is another aspect that should be tested, and that is whether a state-change occurs for an invalid move, which means that a buy is expected to follow an invalid move. This is done by writing a simple test; moveAfterInvalidMoveIsValid (iteration not shown here).

We now move to the next invalid, and that is moving units that are not there (or more than there are). In order to ensure that it is not an defect masking the test must ensure that the *Tile* is owned by the given colour, so it is not the owner-validation that catches (only test one invalid at a time => systematic testing; always a good idea).

1. Create test *redMoveTwoCamelsFromRedOwnedTileWithNoCamelsToBoarderingEmptyUnownedErgInvalid*

2. Test case fails (move performed – results in negative camels at “from”)

3. Implement validation of Camel number (Obvious implementation, as oppose to Fake-it, which only checks if there are any camels. These two implementations are very similar, and it would be a waste to fake it).

4. Test case succeeds.

5. Refactoring – none needed.

We should also test for not enough Camels (other Equivalence and boundary value test), yet this is not included in the report, as only that we should is important, how is easy. We now realise that there is an invalid missing in the original test list. What if we move to a *Tile* that is not bordering? As we see it is important to not simply implement the overall test-list, but to insure that all functionality is tested. The original test-list is merely a guideline. We also realise that all the previous tests are missing some information in their names, namely “Bordering”. We simply assumed this, and we all know what happens with assumptions. This will be fixed in the following refactoring.

Some assumption we have permitted, as e.g. it is assumed that it is Red's turn when all these tests are being run. Is this correct? Well, we think it is a matter of readability, and that it will merely clutter the test-case name even more without contributing to understanding the test; it is a balance.

1. Create test *redMoveTwoCamelsFromRedOwnedTileWithTenCamelsToNonBoarderingEmptyUnownedErgInvalid*

2. Test case fails (move performed)

3. Implement validation that the “to” *Tile* is bordering the “from”.

4. Test case succeeds

5. Refactoring – Update all move tests to specify that the *Tile* is bordering, except of course this one.

Is it likely that the code has been written to distinguish between PlayerColour and *TileType* when checking whether a *Tile* is Bordering? No, not really and we therefore do not need to test the above for the other types and the other colours. We therefore move on to the attacks, which we split up into two; determine if attack is needed and then performing the attack (small steps).

3.4.7 Attack

As for the attack it is simply a variation of a move we can continue along the same lines.

1. Create test *redMoveTwoCamelsFromRedOwnedTileWithTenCamelsToBoarderingYellowOwnedErgWithEightCamlesValid*

2. Test case succeed (it is a valid move, and the move is simply performed.

1. Create test *redMoveTwoCamelsFromRedOwnedTileWithTenCamelsToBoarderingYellowOwnedErgWithEightCamlesResultsInRedOwnershipOfErg*.

2. Test case succeeds (we also not simply move the ownership.

1. Create test *redMoveTwoCamelsFromRedOwnedTileWithTenCamelsToBoarderingYellowOwnedErgWithEightCamlesResultsInTwoCamelsOnErg*. Here we actually had to make a decision, as the specification does not show how we should distribute the remaining camels on the two tiles, we decide to move in with all of them, as you can only attack with all Camels (not the two that you moved – that number is irrelevant).

2. Test case fails (we actually end up with 10 camels (the 2 moved + the 8 yellow)

3. Implement fake-it attack, which identify if an attack is warranted (different owner) and if so always subtracts the “to”-tiles unit number from the “from”-tiles total number. This breaks the test of moving a number of camels to an owned *Tile* with no camels, as here all camels are moved. So we have to update the attack needed algorithm to return true when different owner AND camels on “to”-tile. And then perform the subtraction.

4. Test case succeeds

5. Refactoring – Moving the isAttackNeeded algorithm to separate method to ease readability. There are still a few ifs in the move algorithm, so we might think of a redesign/refactor, yet for now it is still readable, yet switch-creep is a risk.

1. Create test *redMoveTwoCamelsFromRedOwnedTileWithTenCamelsToBoarderingYellowOwnedErgWithEightCamlesResultsInZeroCamelsOnOrriginalRedTile*.

2. Test case succeed

Moving on to the loosing attacks. As all attacks are valid we

1. Create test *redMoveTwoCamelsFromRedOwnedTileWithTenCamelsToBoarderingYellowOwnedErgWithElevenCamlesResultsInYellowOwnershipOfErg*

2. Test case fails

3. Triangulate – We have already implemented the isAttackNeeded, and we now need to determine a winner. To increase readability we again move it to a separate method; isAttackSuccessful, and if not we do not change the ownership of the tiles (the move-algorithm is unchanged).

4. Test case succeeds

5. Refactoring – none needed

1. Create test *redMoveTwoCamelsFromRedOwnedTileWithTenCamelsToBoarderingYellowOwnedErgWithElevenCamlesResultsInOneCamelOnErg*.

2. Test case fails (we still subtract as if the attacker wins => negative units)

3. Triangulate. We need to differentiate between a winning and a losing when moving and use the above method again to determine this, and reverse the subtraction in this case.

4. Test case succeeds

5. Refactoring – none needed.

And finally testing the loser's camels

1. Create test *redMoveTwoCamelsFromRedOwnedTileWithSevenCamelsToBoarderingYellowOwnedErgWithElevenCamlesResultsInZeroCamelsOnRedTile*.

2. Test case succeed (was implemented above as obvious implementation).

We have not dealt with a draw, so we will do so.

1. Create test *redMoveTwoCamelsFromRedOwnedTileWithTenCamelsToBoarderingYellowOwnedErgWithTenCamlesResultsInYellowOwnershipOfErg*. Here the specification was also a little vague. We decided to implement so that the attacking unit needs camel's to enter the *Tile*, and in a draw has none, so the ownership remains in the hands of the attacked.

2. Test case fails (isAttackSuccessful was implemented to return true is equal)

3. Fix algorithm

4. Test case succeeds

5. Refactoring – none needed

Tests for the remaining camels on the ”to” and ”from” tiles is also performed, yet these are left out of the report as they do not supply extra information. Now that we have finished the attack algorithm, we realise that there is a not-attack that has never been tested, and not until now de we realise the potential problem. What if a player moves camel's onto a *Tile* that is already owned by this player and has units on it. In the existing algorithm it is overridden, is it not? The simplest way to find out; write a test.

1. Create test *redMoveTwoCamelsToBoarderingRedOwnedTileWithTwoUnitsResultsInFourCamelsOnTo_Tile*

2. Test case fails. We were right, there is a problem.

3. Triangulate. With the existing implementation we simply change a standard move (non-attack) to add the move number of units to the number of units on the “to”-*Tile*, and this is the number the tile is updated with.

4. Test case succeeds. The reason this is so simple to fix is that we were lucky with our *isAttackNeeded* algorithm, as we looked at ownership first, and not Camel count, as we might in that case only have looked at the Camel-count, and then the implementation would have required more.

5. Refactoring – none needed.

This is the completion of the attack. As we have all our previous move-tests we know that the attack-algorithm has not messed with the standard move, and that is good to know.

3.4.8 Buy

We begin the buy procedure, or rather continue, as we have already implemented the state-change. When we look at the original test-list we realise that it has been completely forgotten. This is naturally not a reason to leave it out, so we begin the process.

1. Create test *redWithTenCoinsBuyFiveCamelsForRedSettlementValid*
2. Test case succeeds (We have already implemented that buy is valid)

1. Create test *redWithTenCoinsBuyFiveCamelsForRedSettlementResultsInFifteenCamelsOnSettlement*
2. Test case fails
3. We First fake-it and simple deploy the specified amount of coins to the indicated Tile. This is the highest level of fake-it we can do to avoid breaking previous tests.
4. Test case succeeds
5. Refactoring – none needed.

Well, how about an invalid purchase

1. Create test *redWithTenCoinsBuyElevenCamelsForRedSettlementInvalid*
2. Test case fails (we always allow buy)
3. Triangulate – We validate that the player in turn has the specified amount of money and if not return false.
4. Test case succeeds
5. Refactoring – We have to consider if we want to move validation out as a strategy-pattern just like with move. We decide to postpone it, as there is no responsibility conflict, and the code is still readable.

1. Create test *redWithTenCoinsBuyTwoCamelsForGreenSettlementInvalid*
2. Test case fails (we only validate sufficient coins)

3. More triangulation – We validation that the deployment-*Tile* is owned by the current player. We could fake-it and say it should be owned by Red, but it would be fake-it for the sake of faking.

4. Test case succeeds

5. Refactoring – Is it now we should move the validation out of Game? We decide to wait, as it is still quite readable.

   What's next – well, we can only place on the Settlement, so we should try and place some Camels where it would normally be valid (by the overall rules), like an owned tile that is not a *Settlement*.

1. Create test *redWithTenCoinsBuyTwoCamelsForRedOwnedErgInvalid*

2. Test case fails

3. Triangulate – update test to only allow purchases to be placed on Settlements (must naturally also meet other requirements)

4. Other test case fails. We realise we have a problem with the yellow revenue test, as we cannot purchase anything while not having a settlement, and therefore not get a revenue calculation. What to do? We cannot use another player, as there is the same problem. He can never complete his turn without a *Settlement*? We decide for a quick-fix, and note the error in the requirements, and simply make an exception for buy-count = 0. This is not a proper solution, though, it is a nasty HACK. The requirements needs to be updated to specify what should happen, as we otherwise have a dead-lock.

5. Test cases succeed.

6. Refactoring – Here we could argue that it is getting so complex it warrants a separate class, but we believe it is still easily readable.

   We have also not validated that the other TileTypes are not different, but we are confident they are handled the same (same EC). We could try a buy outside the board, but just like the previous the GUI would not allow it, so it is not a "valid" test - it is sufficient to simply document it, as is done in Position (only 0 – 6 is valid). We should naturally perform the same buy tests for the other players, but this has been left out of the report as it is similar to the above, except they succeed.

3.4.9 Revenue

With the revenue calculation we could look at all possible combinations of all tiles and ownership and write a test case for it, but that would give more test-cases than we care to think off, and it would not be in tune with the idea of using logic, as it does not take that long. Just like with the *Tile*-layout we have the option of using systematic testing and test all valid in one test case or TDD and test one at a time. We need at least one test case for each *Tile*-type with a given ownership, or one test case put together so that all tiles types has an owner, and so that the sums may only come from a given combination of Tiles. Naturally this will allow for error-masking, but only if two errors

cancel out each other, e.g. settlement is 5 should be 4 and erg is 2 should be 3. If the same player owns these two we cannot see the error. How likely is this? Many orders of magnitude are smaller than a single *Tile* type failure. We do however decide to take small steps and implement a test for each *TileType*. We do however deem the colours to be handled identically, and we therefore only test one colour for all Tiles, as will be seen.

1. Create test *revenueRedWithSettlementGivesFourteenUnitsToRed*. Fourteen is due to the initial 10.

2. Test case fail

3. As we have already dealt with the units before (during player test we tested the initial value) we cannot simply fake it and return 14 (would make initial count test fail), we have to triangulate. We calculate revenue at end round (when circular-buffer turns). We find this out by updating the circular buffer to signal when it has completed a round. We decide to do this with an *observer pattern*, where the *Game* implementation may listen for a round completion. We could of course have kept a secondary counter or hard-coded that when the player returned to Red we should calculate revenue, but that would violate the entire principle of moving the round-maintenance to the circular buffer. We therefore implement the observer pattern and realise another advantage. As the circular buffer is a strategy pattern it is used via an interface, and is therefore under testing control, and we write a test version which trigger the revenue (by eventing round-done) the first time a turn is completed. This simplifies the unit test greatly, as we do not have to complete a whole round. We fake-it the revenue calculation and simply giving red 4 units.

4. Test case succeeds.

5. Refactoring - none needed.

We once again got stuck with an implementation that looks bigger than small. When one realise the potential for the use of a design pattern it is often a larger undertaking to implement it, and it is rare that the first test in the TDD will reveal this. There seems to be an inherent un-will to user overall design in the TDD process – very much like the XP process, which may result in well tested and quickly written code, but also makes it difficult to get an over-all understanding (no architectural documentation, as the architecture is not understood). Moving on.

1. Create test revenueRedWithSettlementAndSaltMineGivesNineteenUnitsToRed. Here we take advantage of the *BoardFactory* interface, and insert a *TestBoardFactory* that return the ownership we want, and therefore do not have to move around in order to test revenue.

2. Test case fail – only get 14.

3. Triangulate – we need a matching between *TileType* and Economic value. There are several ways of doing this;

    1. Create a big switch and let the *Game* implementation decide.

2. Create a method on *Board* to retrieve an Economic value from a *TileType*.

3. Create a strategy-pattern and have this interface map the *TileType* to an Economic value.

4. Making it part of the *TileType* enum (due to Java's implementation of enums)

5. Create method on *Tile* and retrieve from there.

   There are plenty of advantages and disadvantages to these. From a logic standpoint the Economic value follow the *TileType*, indicating the enum solution. The problem with this one is mostly readability. Will a future reader understand what is going on, as it is a bit of a Java-trick? We fear not, so we choose against this. The strategy pattern allows for the replacement of economic values at runtime, yet as we have no such requirement at the moment this may be overkill. This leaves us with the switch solutions and the *Tile* interface update. As it is not the responsibility of neither *Game* nor *Board* to know determine the monetary value of a *Tile* we choose the *Tile* update and add the method *getEcconomicValue* to the interface. The implementation may also be a switch or a value. If we choose a value it may be replaced at runtime, yet as we have no such requirement we choose a simple switch solution. The first implementation contains only *Settlement*. The implementation in *Game* is a simple iteration and accumulation of all (obvious implementation)

4. Test case succeeds.

5. Refactoring - none needed.

The remaining *TileType* test-cases are simply adding to the switch in the StandardTile implementation, so they are not included here, but they follow the rhythm quite well. These test-cases are left out of the report. We continue with the other colours.

1. Create test *revenueGreenWithSettlementGivesFourteenUnitsToGreen*.

2. Test case fails (only Red got revenue)

3. Triangulate – we update the code to also give Green revenue (obvious implementation to include the actual revenue calculation as for Red).

4. Test case succeeds.

5. Refactoring – none needed.

This is continued for the other two colours, yet this gives nothing to the academic knowledge so it is left out. We continue with the odd-situations; no settlement.

1. Create *revenueYellowWithErgButNoSettlementGivesTenUnitsToYellow*, i.e. no revenue (again this is simply done with our *TestBoardFactory*).

2. Test case fails.

3. Triangulate. We need to implement a check of whether Yellow has a settlement, and we do this during the revenue-calculation (simply set a flag is a settlement is found). This is relatively simple, and we do it for all four *PlayerColor* as obvious implementation

4. Test case succeeds

5. Refactoring – none needed.

Here we see a nice rhythm again, and with the obvious implementation the test of each of the Four PlayerColor missing a Settlement will succeed. We have left these iterations out of the report.

We move on to the other special case; a dead player. This turns out to be a little more difficult to implement, or rather requires some significant changes, as will be shown.

1. Create test *yellowLoosesOnlyTileResultsInPlayerCountThree* (again using *TestBoardFactory*). As the player-count is only available in the Board, and the board is the one who maintains the players, it is tested in the TestAlphaBoard

6. Test case fails (Yellow is still include in the *Player* count)

7. Well, we need to update the player count under a special condition, which is that there are no Tiles owned by Yellow. This is easily done by iterating all Tiles, but when do we need to perform this. The easiest is simply to have *Board* do the evaluation every time a *Tile* is updated. You could also do it only when a *Tile* changes owner, but as we have plenty of processing power we can afford to splurge and get some readability instead. As we do not test the player count after a move at any point in time we could simply remove read after the first move, but that is more like looking for a way to fake-it that we know will cost us extra work. We therefore take the high road and implement the iteration correctly. We create a private method on the *Board* implementation; updatePlayers(), which scans the Tiles for the PlayerColors in the collection of players and remove the ones that are not found. This will also affect the count.

8. Test case succeed

9. Refactoring 1 – We realise that there is a potential mismatch between the players returned by the *BoardFactory* and the *Board* layout returned by the same factory. We therefore perform an updatePlayers in the constructor after creating the *Board* layout, thereby erasing any players that should never have been on the board.

10. Refactoring 2 – There seems to be a funny situation with the player count. We have a requirement that there are initially four players, but there is no need for a method returning a player-count – at least the method is never used outside the tests. It is dead-code, and it should be removed, yet we cannot easily replace it with something else. We have methods to get a specific *Player* given his or her colour, but the number of players hidden behind the *Board* may be more (if there were more than four colours). This means that a unit test that checked that there

is a Red, Green, Blue and Yellow player is insufficient, as it will not catch if a Pink player is added (requires that the enum is expanded). We therefore choose to move the method from the interface and create special *TestBoard* interface which has the method, and let *AlphaBoard* inherit from both *TestBoard* (which extends *Board*). This is an acceptable solution that keeps the code for testing purposes, but does not show it to the production code.

We have now implemented the death of a player, but have not considered the game flow. What happens to the rounds? Do we update the Round algorithm in the strategy pattern and teach it about Players? Bad idea as it mixes responsibilities. We need to code to skip the dead player, though. Let's see what TDD would do.

1. Create test *currentPlayerAfterRedWithGreenDeadIsBlue*. Here we again use the *TestBoardFactory* to create a board with no Green Tiles, i.e. Dead Green player. The refactoring above makes this work.

2. Test case fails – (null reference exception)

3. We cannot allow the dead players to get their turn, as they have nowhere to place bought camels, even if they have units, and as the *Player* has been removed from the *Board* it cannot be retrieved. Presently the Java implementation of the HashMap return null if the key is not found. Some languages see this as an exception, as they specify that the key MUST be present. We could handle this null-value and use it to ignore the player, but that is placing a protocol into the return value object and that always makes for unreadable code. We prefer to see the returned null-value more like an exception and exceptions are meant to deal with exceptional situations, and a dead player is not exceptional, it is quite predictable. We therefore use the same trick as most programming languages use to at least limit the likelihood of an exception; first ask if the call is valid and then, if it is, perform it. E.g. If key exist in hash-table get value, otherwise don't. We update the *Board* interface with a method *hasPlayer(PlayerColor)* which returns if the player is in the Map. (Obvious implementation). If this method returns false we simply ask for the next *PlayerColor* from the *PlayerTurnStrategy*.

4. Test case succeeds.

5. Refactoring – We realise that in one of the very first test cases we actually did make the assumption that null meant player do not exist. This is of course in test code so the rules are a little more lenient, but at the same time we should not have un-pretty code. We could change the test to use the hasPlayer check, but then we would not actually verify that the player is returned in that test case, but since several other (e.g. testing that the player returned on Green also has a Green *PlayerColor*) it is not a problem. We should update with test cases for *hasPlayer* for Green, Blue and Yellow, as we left these out.

This may look like a victory, but what if two players die very unfortunately; Yellow kill Green and Red kill Blue?

1. Create test *currentPlayerAfterRedWithGreenAndBlueDeadIsYellow*.

2. Test case fails – (null reference exception)

3. Why did this explode? Because it is assumed that the next player in line is valid, it is not validated. How do we fix this? The simplest is a while loop that continues asking for the next *Player* from the *PlayerTurnStrategy* until it gets one that is valid. Is there a risk with such a while-loop? As with all self-controlling while-loops it can create an infinite loop, in this case if player count reaches 0. As this is an impossibility, unless the *BoardFactory* returns it, this is handled by simply making initial player count = 0 illegal by convention. It would also be pretty boring game.

4. Test case succeeds.

5. Refactoring – none needed.

We have now handled the dying players and we move on to the last part of the *Game*; the winning. We hit our first snag in writing the test. How do we determine if there is a winner? There is an eventing system which can send a text-string which we can then parse. This is a solution, yet not a preferable one. We use TDD to solve the problem.

3.4.10 Winner

1. Create test winnerInFirstRoundIsNone

2. Test case fails (no such method)

3. We need a method to determine the winner, and create *getWinner*(), which returns a *PlayerColor* if a winner is found or *PlayerColor.None* if the game is ongoing. We fake-it implements this to return *PlayerColor.None*.

4. Test case succeeds.

5. Refactoring – none needed.

We could test for a heap of other none-win situations, but they would all succeed, so what is the fun in that. We move on to the win situation. We realise that there is no way to set round count, and we have no interest in performing 25 * 4 buy. Naturally this can be done quickly in a loop, but still; there must be a more elegant solution, and there is. The win is determined by a round count and the rounds are controlled by the *PlayerTurnStrategy*. It is therefore a brilliant place to store the round count and then simply create a TestStub for the test. We use this idea to write the test, inventing the names as we write the test.

1. Create test *redOwnsSaltMineAfterTwentyfiveTurnsGivesRedWinner*.

2. Test case fails. (compile error, no such method)

3. We first implement the method *getRoundCount* on the *PlayerTurnStrategy* interface. As we already event the revenue calculation on a completed round we have the perfect place to update our count. This is an obvious implementation.

As to the winner we fake-it and return Red if round count >= 25 (we could probably have obvious implemented this, but let's do one more iteration with a nice rhythm). We then set the current round count in the *TestPlayerTurnStrategy* implementation.

4. Test case succeeds

5. Refactoring – none needed.

As we still have one fake-it we create.

1. Create test *yellowOwnsSaltMineAfterTwentyfiveTurnsGivesYellowWinner*.

2. Test case fails

3. Triangulate – Now we have the problem. How do we get the SaltMine, and which one (only the board knows how many there is). The requirement places the salt-mine at 3,3, but the game does not know this. We now have to decide if we want to implement a strategy-pattern to place the "determine winner"-strategy in, or we can place it in the Game implementation. We decide on the latter strategy, as we do not have a responsibility conflict (and do not know of any reason to have a variability-point). We do not want to hard-code the Position(3,3) as the winner, and instead iterate the Board for TileType.SaltMine. This means the result is not the owner of Position(3,3), but rather the owner of the first SaltMine, which should be the same.

4. Test case succeeds.

5. Refactoring – none needed.

As it may be seen we have decided to continue the game if no-one owns the SaltMine after 25 turns, instead of terminating it. This means that if anyone gets the SaltMine after the 25th turn they instantly win. This is also why we chose to make the code round count >= 25 and not == 25.

3.5 Conclusion

That is the implementation of the AlphaTargui based on TDD. We have made some comments during the process, and here we sum up on a few of our points and also add some more thoughts.

As it may be seen we have not included any diagrams, as we believed it would take focus away from the process. The document and code has been written as an ongoing process with one iteration leading to the next, and with very little stopping up to look at the big picture – keeping focus. We have, however, as part of the conclusion created a class diagram showing the different static parts of the system, just to give an overview. This may be seen in Figure 2.

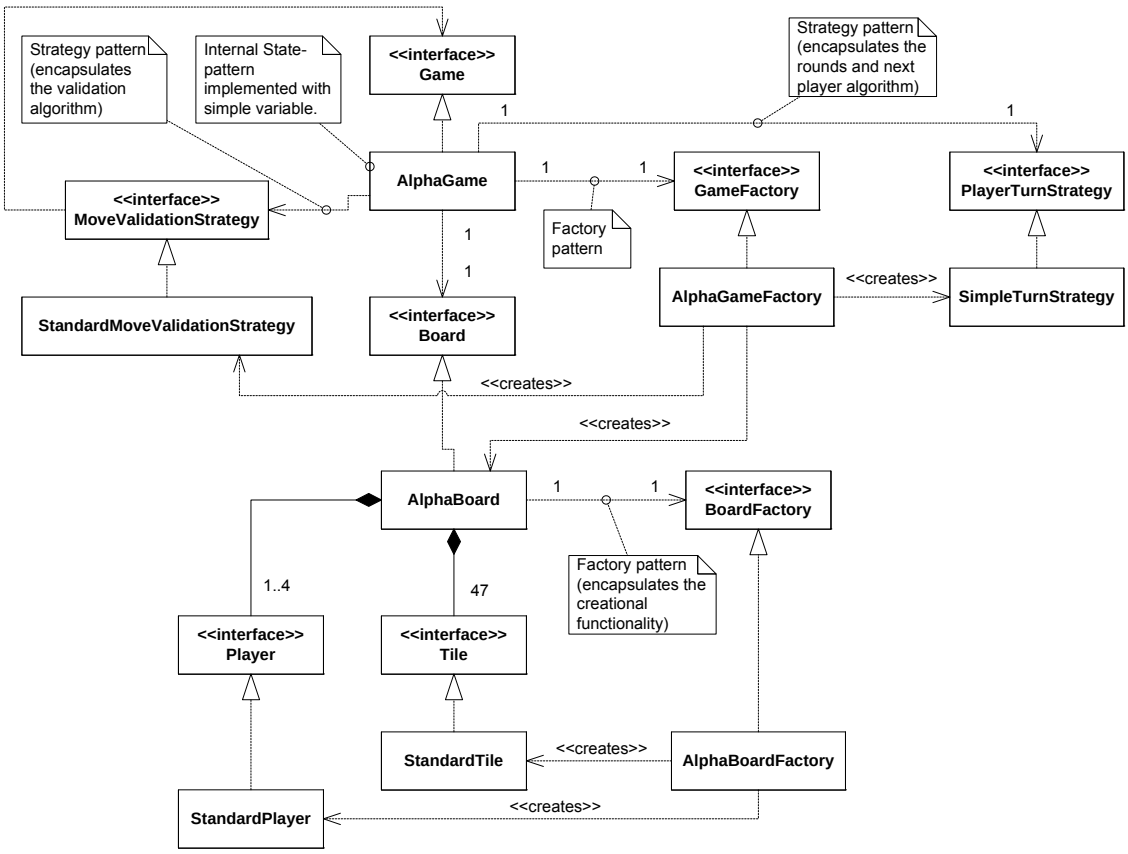


Figure 2

It is interesting to see how the TDD rhythm works much better when the interfaces (and implementation) of the types the UUT is dependent on is defined and implemented and we only have to alter the UUT itself. This can be seen as the different overall tests (each including several test-cases) reaches their conclusion. The last test-cases are always following the rhythm quite nicely, where the first has “larger” implementation or refactoring. We believe this is to be expected when TDD is used to define the interfaces as the process progress, just like in a traditional design phase, it is always important to define the interfaces and responsibilities first, and make sure that this is complete, in

order to avoid major refactoring during implementation (here code is included in the design phase, as the proof of concept usually means writing production code where needed, and faking it where possible until the chain is complete). After that all the in depth implementation starts; the kind that does not require in-depth understanding of the design.

We have considered if a test perhaps should be removed if it seems too big, but it creates tests that does not have any hold in the requirements. This may be a better approach, in hindsight, as some of the implementations actually contained iterations inside them (at least from a coding point of view). Of course having to stop mid-iteration to break the test up into smaller tests also interrupt the rhythm, so we would still have the problem.

We can also see that we have reused many of the same TileTypes, e.g. the Erg is used almost everywhere. From a Systematic Testing point of view this is silly, as we should have used as many different as possible to get maximum chance of finding defects.

The assignment itself may also not be the best suited for TDD. At a seminar it was once pointed out that “if you knew exactly what you were doing, then why waste time on iterative processes, when the waterfall-model works perfectly for those projects”, and also “if you know all the requirements in detail then why are you looking at the project, send it to India”. The point is that most projects are not as well specified as this one, and TDD gives some good possibilities of implementing what you can and postponing or encapsulating what you do not know, giving it more merit in those projects.

An alternative to TDD which it is believed would also have give a good result with less overhead is Responsibility Driven Design, and after the CRC cards design the Software Architecture, thereby getting a full understanding of dependencies, which would have discovered problems like the *Board* needing to know who's turn it is in order to validate move. This would have defined the interfaces, and Systematic Test could have been used on the individual interfaces and also there implementations (in same test perhaps), as fault detection, giving high reliability and readability (the design).

4 Systematic Test

4.1 Introduction

We are going to make a systematic black-box testing of the BetaTargui attack algorithm. In black-box testing we don't have access to the production code.

A hint was given to this exercise that the best test investment is to concentrate on the kill algorithm.

We should consider the BetaTargui function to be tested to be:

killed = k(f, t, Uf, Ut, Sf, St, d);

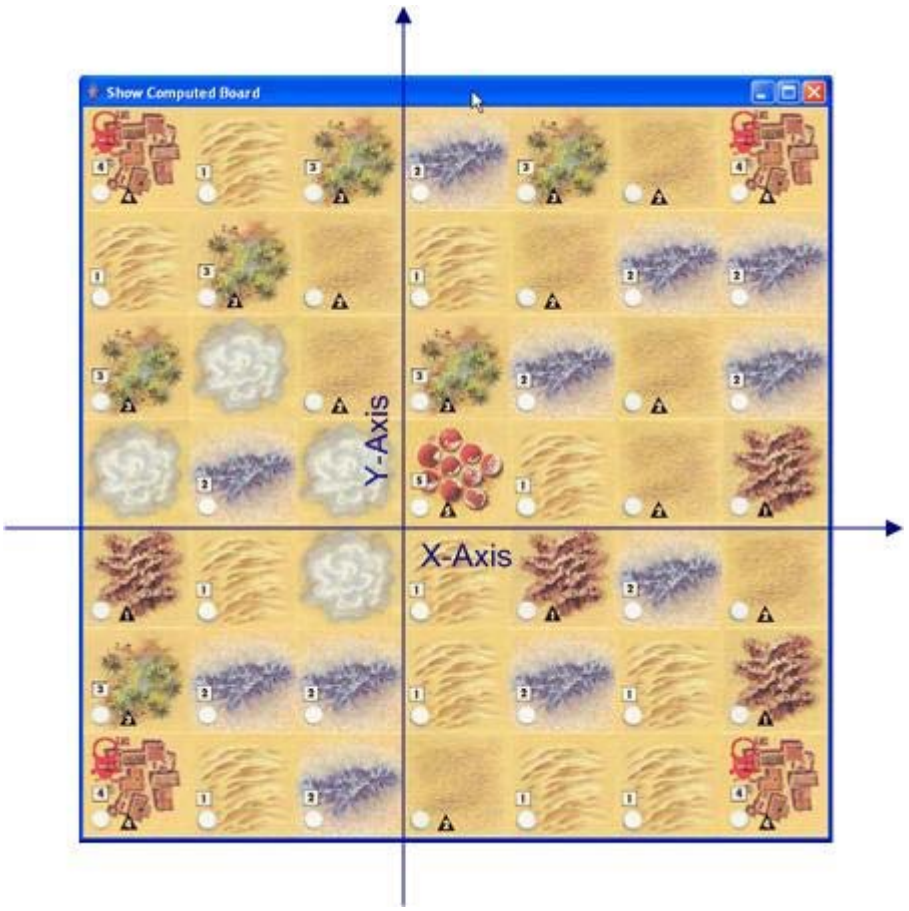
where 'killed' is the expected answer according to the Targui rules, 'k' the computed answer - our system testing effort must make us confident that the above equation is true under all circumstances. The parameters have the following domains:

- f: from tile {(0,0), ... (6,6)}
- t: to tile {(0,0), ... (6,6)}
- Uf: units on from tile { 1, ... infinity}
- Ut: units on to tile { 1, ... infinity}
- Sf: strategic value of from tile { 0,1,2,3,4,5 }
- St: strategic value of to tile { 0,1,2,3,4,5 }
- d: die roll value {1,2,3,4,5,6}

We will use the abbreviations and the domain delimitations in the following assignment. For instance we will not waste time on testing if there are any units on from tile.

4.2 Finding partition sets - distance

The figure below should illustrate that you could move the camels either in the X-axis direction (horizontal), in the Y-axis direction (vertical) or in both direction at the same (diagonal).



The first considerations regarding finding partition sets:

Dimensions	Type	Values	No. of partition sets
X-axis	range	-6 to 6	3
Y-axis	range	-6 to 6	3

Defining X-axis and Y-axis as separate range of values are not very useful, as they are coupled parameters. Let's try another way.

As when you just move camels we may only attack neighbour tiles. Thus we have to test if you are allowed to attack the attacked tile. Or in other words: is the distance between the tiles correct?

The distances can be calculated as:

$X_{dist} = X_f - X_t$

$Y_{dist} = Y_f - Y_t$

where X_f and Y_f specifies the tile where you attack from and X_t and Y_t specifies the tile you attack.

We can either test each dimension (X_{dist} and Y_{dist}) separately or on a function of the two dimensions. To reduce the number of partitions we choose to test on both dimensions at the same time. It gives the following partition table with 13 partitions ([A1] to [A13]):

Dimensions	Invalid partition	Valid partition
"X_{dist}, Y_{dist}"	X_{dist} < -1 [A1] Y_{dist} < -1 [A2] X_{dist} = 0; Y_{dist} = 0 [A3] X_{dist} > 1 [A4] Y_{dist} > 1 [A5]	X_{dist} = -1; Y_{dist} = -1 [A6] X_{dist} = -1; Y_{dist} = 0 [A7] X_{dist} = -1; Y_{dist} = 1 [A8] X_{dist} = 0; Y_{dist} = -1 [A9] X_{dist} = 0; Y_{dist} = 1 [A10] X_{dist} = 1; Y_{dist} = -1 [A11] X_{dist} = 1; Y_{dist} = 0 [A12] X_{dist} = 1; Y_{dist} = 1 [A13]

You may argue that invalid distance (invalid partitions A1-A5) should be covered by move() and not by the kill() function. But move() has not been covered by systematic test and since it is black-box test we don't know if the programmer has done his job well.

4.3 Result of attack

We don't need to test if attacker has some camels to attack with, because the Targui domain code will never throw a value less than 1. It gives us one new valid partition:

Dimensions	Invalid partition	Valid partition
Uf		Uf > 0 [B1]

Next we have to test how many camels are killed and how many camels are left after the attack.

The number of camels killed by an attack can be calculated as:

$$F1_{Killed} = \text{Math.round}((d_1 + Sf)/2)$$

where d_1 = "die roll value" and Sf = "strategic value of from tile". Math.round () is function that rounds a number downwards towards the next lowest number.

Because the number of killed camels depends on d1 and Sf we get two new dimensions. Both d1 and Sf are set of values, which leads to a partition for each member and normally one for non-members. But because a die can't throw a value outside the set of values (1-6) and because the Targui domain code will never throw a value outside the set of values (0-5), we don't have any invalid partition.

Dimensions	Invalid partition	Valid partition
d_1		1 [C1] 2 [C2] 3 [C3] 4 [C4] 5 [C5] 6 [C6]
Sf		0 [D1] 1 [D2] 2 [D3] 3 [D4] 4 [D5] 5 [D6]

The next thing we have to test is if there are any camels left on the attacked tile:

$$Ut > F1_{killed}$$

And it gives the following dimension (or two new partitions [E1] and [E2]).

Dimensions	Invalid partition	Valid partition
$F1_{Killed}$, d_1, Sf		$Ut - F1_{killed} > 0$ [E1] $Ut - F1_{killed} <= 0$ [E2]

If $Ut > F1_{killed}$ (partition [E1]) the defender is allowed to re-attack the attacker.

The numbers of camels killed by a re-attack are calculated on a similar way as by the first attack.

$$F2_{Killed} = Math.round((d_2 + St)/2)$$

where d_2 = “defenders die roll value” and St = “strategic value of to tile”.

Because the number of killed camels depends on d_2 and St we get two new dimensions and a similar set of partition as for the first attack:

Dimensions	Invalid partition	Valid partition
d_2		1 [F1] 2 [F2] 3 [F3] 4 [F4] 5 [F5] 6 [F6]
St		0 [G1] 1 [G2] 2 [G3] 3 [G4] 4 [G5] 5 [G6]

4.4 Equivalence classes

Equivalence classes are the cross product of the partition sets. I our case it would give 13 x 1 x 6 x 6 x 2 x 6 x 6 = 33.696 combinations. Of course we can't test all these combinations so we will apply Myers recommendations for finding test cases.

According to Myers formulation you only have to test a single invalid partition one time and that it should be in combination with only valid partitions. 5 invalid partitions ([A1] to [A5]) give 5 test cases.

TestCase1: [A1] x [B1] x [C1] x [D1] x [E1] x [F1] x [G1]
TestCase2: [A2] x [B1] x [C1] x [D1] x [E1] x [F1] x [G1]
TestCase3: [A3] x [B1] x [C1] x [D1] x [E1] x [F1] x [G1]
TestCase4: [A4] x [B1] x [C1] x [D1] x [E1] x [F1] x [G1]
TestCase5: [A5] x [B1] x [C1] x [D1] x [E1] x [F1] x [G1]

Myers also says that you need to cover all valid partitions. To do that you need 8 test cases to cover the dimension "X_{dist}, Y_{dist}" (partition [A6] to [A13]). All other partitions are covered at least one time.

TestCase6: [A6] x [B1] x [C1] x [D1] x [E1] x [F1] x [G1]
TestCase7: [A7] x [B1] x [C2] x [D2] x [E2] x [F2] x [G2]
TestCase8: [A8] x [B1] x [C3] x [D3] x [E1] x [F3] x [G3]
TestCase9: [A9] x [B1] x [C4] x [D4] x [E1] x [F4] x [G4]
TestCase10: [A10] x [B1] x [C5] x [D5] x [E1] x [F5] x [G5]
TestCase11: [A11] x [B1] x [C6] x [D6] x [E1] x [F6] x [G6]
TestCase12: [A12] x [B1] x [C1] x [D1] x [E1] x [F1] x [G1]
TestCase13: [A13] x [B1] x [C1] x [D1] x [E1] x [F1] x [G1]

Using Meyer's recommendation we have now only 13 cases to test.

4.5 Test cases

Equivalence class	Inputs	Expected output
TestCase1: [A1] x [B1] x [C1] x [D1] x [E1] x [F1] x [G1]	[A1]: X_{dist} = -2; Y_{dist} = 0; (X_f=4; X_t=2; Y_f=4; Y_t=4) [B1]: Uf = 2 [C1]: d_1 = 1 [D1]: Sf = 0 [E1]: Ut – $F1_{Killed}$ > 0 where $F1_{Killed}$ = Math.round((d_1 + Sf)/2) Ut = 2 => 2 - Math.round((1 + 0)/2) > 0 [F1]: d_2 = 1 [G1]: St = 0	Error (Attack not carried out)
TestCase2: [A2] x [B1] x [C1] x [D1] x [E1] x [F1] x [G1]	[A2]: X_{dist} = 0; Y_{dist} = -2 [B1] – [F1] have the same values as in TestCase1	Error (Attack not carried out)
TestCase3: [A3] x [B1] x [C1] x [D1] x [E1] x [F1] x [G1]	[A3]:X_{dist} = 0; Y_{dist} = 0 [B1] – [F1] have the same values as in TestCase1	Error (Attack not carried out)
TestCase4: [A4] x [B1] x [C1] x [D1] x [E1] x [F1] x [G1]	[A4]: X_{dist} = 2; Y_{dist} = 0 [B1] – [F1] have the same values as in TestCase1	Error (Attack not carried out)
TestCase5: [A5] x [B1] x [C1] x [D1] x [E1] x [F1] x [G1]	[A5]: X_{dist} = 0; Y_{dist} = 2 [B1] – [F1] have the same values as in TestCase1	Error (Attack not carried out)
TestCase6: [A6] x [B1] x [C1] x [D1] x [E1] x [F1] x [G1]	[A6]: X_{dist} = -1; Y_{dist} = -1 (X_f=4; X_t=3; Y_f=4; Y_t=3) [B1]: Uf = 2 [C1]: d_1 = 1 [D1]: Sf = 0 [E1]: Ut – $F1_{Killed}$ > 0 where $F1_{Killed}$ = Math.round((d_1 + Sf)/2) Ut = 2 => 2 - Math.round((1 + 0)/2) > 0 [F1]: d_2 = 1 [G1]: St = 0	1. Attack carried out Uf = 2; Ut = 2 2. Re-attack carried out Uf = 2; Ut = 2 3. Attacker gives up Uf = 2; Ut = 2
TestCase7: [A7] x [B1] x [C2] x [D2] x [E2] x [F2] x [G2]	[A7]: X_{dist} = -1; Y_{dist} = 0 [B1]: Uf = 2 [C2]: d_1 = 2 [D2]: Sf = 1 [E2]: Ut = 2 => 2 - Math.round((2 + 2)/2) <= 0 [F2]: d_2 = 2 [G2]: St = 1	Attack carried out Uf = 2; Ut = 0

TestCase8: [A8] x [B1] x [C3] x [D3] x [E1] x [F3] x [G3]	[A8]: X_{dist} = -1; Y_{dist} = 1 [B1]: Uf = 2 [C3]: d_1 = 3 [D3]: Sf = 2 [E1]: Ut = 3 => 3 - Math.round((3 + 2)/2) > 0 [F3]: d_2 = 3 [G3]: St = 2	1. Attack carried out Uf = 2; Ut = 1 2. Re-attack carried out Uf = 0; Ut = 1
TestCase9: [A9] x [B1] x [C4] x [D4] x [E1] x [F4] x [G4]	[A9]: X_{dist} = 0; Y_{dist} = -1 [B1]: Uf = 2 [C4]: d_1 = 4 [D4]: Sf = 3 [E1]: Ut = 4 => 4 - Math.round((4 + 3)/2) > 0 [F4]: d_2 = 4 [G4]: St = 3	6. Attack carried out Uf = 2; Ut = 1 7. Re-attack carried out Uf = 0; Ut = 1
TestCase10: [A10] x [B1] x [C5] x [D5] x [E1] x [F5] x [G5]	[A10]: X_{dist} = 0; Y_{dist} = 1 [B1]: Uf = 2 [C5]: d_1 = 5 [D5]: Sf = 4 [E1]: Ut = 5 => 5 - Math.round((5 + 4)/2) > 0 [F5]: d_2 = 5 [G5]: St = 4	1. Attack carried out Uf = 2; Ut = 1 2. Re-attack carried out Uf = 0; Ut = 1
TestCase11: [A11] x [B1] x [C6] x [D6] x [E1] x [F6] x [G6]	[A11]: X_{dist} = 1; Y_{dist} = -1 [B1]: Uf = 2 [B6]: d_1 = 6 [C6]: Sf = 5 [D1]: Ut = 6 => 6 - Math.round((6 + 5)/2) > 0 [E1]: d_2 = 6 [F6]: St = 5	1. Attack carried out Uf = 2; Ut = 1 2. Re-attack carried out Uf = 0; Ut = 1
TestCase12: [A12] x [B1] x [C1] x [D1] x [E1] x [F1] x [G1]	[A12]: X_{dist} = 1; Y_{dist} = 0 [B1]: Uf = 2 [C1]: d_1 = 1 [D1]: Sf = 0 [E1]: Ut = 2 => 2 - Math.round((1 + 0)/2) > 0 [F1]: d_2 = 1 [G1]: St = 0	6. Attack carried out Uf = 2; Ut = 2 7. Re-attack carried out Uf = 2; Ut = 2 8. Attacker gives up Uf = 2; Ut = 2
TestCase13: [A13] x [B1] x [C1] x [D1] x [E1] x [F1] x [G1]	[A13]: X_{dist} = 1; Y_{dist} = 1 [B1]: Uf = 2 [C1]: d_1 = 1 [D1]: Sf = 0 [E1]: Ut = 2 => 2 - Math.round((1 + 0)/2) > 0 [F1]: d_2 = 1 [G1]: St = 0	1. Attack carried out Uf = 2; Ut = 2 2. Re-attack carried out Uf = 2; Ut = 2 3. Attacker gives up Uf = 2; Ut = 2

4.6 Boundary analysis

Referring to the domain delimitations:

- f: from tile {(0,0), ... (6,6)}
- t: to tile {(0,0), ... (6,6)}
- Uf: units on from tile { 1, ... infinity}
- Ut: units on to tile { 1, ... infinity}
- Sf: strategic value of from tile { 0,1,2,3,4,5 }
- St: strategic value of to tile { 0,1,2,3,4,5 }
- d: die roll value {1,2,3,4,5,6}

we can't find any boundary cases.

The coordinates for the tiles have been defined to be between (0,0) and (6,6) and distance (X_{dist} or Y_{dist}) can be 0, 1 or greater than the numeric value of 1. We have tested all 3 cases regarding distance.

The strategic values and the die roll values have been defined to be between 0 and 5 and between 1 and 6 respectively. All cases have been covered by the test cases.

Re-attack has also been tested, so we can't find any further things to test.

4.7 Implementation of systematic test case

Implementation of the systematic test case is done in SystematicTest.java. When implementing the test cases we discovered that 4 of the test cases (7, 9, 10 and 11) could not be carried out. For instance test case 7 assumes that there are 2 neighbour tiles with the strategic value 1. But that is not the case, so to carry out all 13 test cases we have to reorganise the partitions. This has not been done yet, and it is the question if it is the effort worth to do it, because we have learned that we have used overpartitioning.

4.8 Lesson learned

The 8 valid partitions A6-A13 is overpartitioning, because this test assumes that we had implement it using a switch with 8 cases.

5 BetaTargui

5.1 Introduction

BetaTargui is identical to AlphaTargui except for the 3 variability points “Turn”, “Attack” and “Winner”. Finding variability points is the first step (step 3) in the 3-1-2 process.

To create the different game variants with different strategies we use the Abstract Factory Pattern:

```
public interface GameFactory{
            Board createBoard();
            PlayerTurnStrategy createTurnStrategy();
            MoveValidationStrategy createMoveValidationStrategy();
            PutUnitsStrategy createPutUnitsStrategy();
            AttackStrategy createAttackStrategy();
            WinnerStrategy WinnerStrategy();
}
```

As the two game variants are identical except for the variability points and the fact that the configuration happens in the factory, we replace AlphaGame with StandardGame. It just looks nicer and gives more meaning when creating the different games:

```
            StandardGame game = new StandardGame();
            GameFactory gameFactory = new BetaGameFactory(game);
            game.setGameFactory(gameFactory);
            game.newGame();
```

5.2 Variability points

Different game rules for the same variability point, can be implemented by encapsulate each one behind an interface to make them interchangeable. This is the Strategy pattern and it lets the rules vary independently from the clients that use it.

Programming to an interface (step 1 in the 3-1-2 process) support a black-box view of the implemented classes and the use of polymorphic. We achieve low coupling and increase testability of the different game variants.

5.2.1 PutUnitsStrategy (Turn)

Responsibility:
Determine if the tile is a valid place to put units after they are bought.

```
public interface PutUnitsStrategy{
            Boolean isPutValid(Player p, Tile t);
}
```

Implementation :
Variability point is found in buy() in StandardGame.java

```
    if ((p.getCoins() >= count && putUnitsStrategy.isPutValid(p, t))
|| count == 0)
```

New source files: PutUnitsStrategy.java (<<interface>>).
Behaviour is delegated to the subordinate objects (step 2 in the 3-1-2 process) in AlphaPutUnitsStrategy.java and BetaPutUnitsStrategy.java.

New test file: TestPutUnitsStrategy.java

The code for BetaPutUnitsStrategy is very simple – almost obvious implementation. It was also easy to bring PutUnitsStrategy under test control. We wrote 3 simple test cases that covers putting unit on own tile, on other tile and on empty tile.

We feel confident about implementing AlphaPutUnitsStrategy when all test cases for AlphaTargui succeeded.

5.2.2 WinnerStrategy

Responsibility:
WinnerStrategy Returns the winner of the game, if any.

```
public interface WinnerStrategy{
          PlayerColor getWinner();
}
```

Implementation :
Variability point is found in getWinner() in StandardGame.java:

```
          return winnerStrategy.getWinner();
```

New source files: WinnerStrategey.java (<<interface>>). Behaviour is delegated to AlphaWinnerStrategy.java and BetaWinnerStrategy.java.

New test file: TestWinnerStrategy.java.
To bring WinnerStrategy under test control we wrote 5 test cases that cover if 2 players have equal revenue and if Red, Green, Blue or Yellow respectively is the winner.

Again we feel confident about implementing AlphaWinnerStrategy when all test cases for AlphaTargui succeeded.

5.2.3 Throw of a die

Attack actions in BetaTargui contain a throw of a die. To bring a throw of a die under test control we program to an interface. This results in to new files: Die.java (<<interface>>) and StandardDie.java (implementation).

```
public interface Die {
		public void rollDie();
		public void setValue(int val);
		public int getValue();
}
```

Test case “testDieValue” was added in TestAttackStrategy.java.

```
  @Test
  public void testDieValue() {
	Die die = new StandardDie();
	die.rollDie();
	int res = die.getValue();
	assertTrue(1 <= res && res <= 6);
  }
```

5.2.4 AttackStrategy

Responsibility:
Handles attack actions, for instance:
- Decides the next state after an attack
- Updates the tiles after an attack

```
public interface AttackStrategy{
		public State moveAttack(Tile tFrom, Tile tTo);
		public State dieRolled(int dieValue);
		public State givingUp();
}
```

Implementation:
The AttackStrategy is quite more complex than the other strategies for BetaTargui, so to get a better overview over the move/attack actions we took a look at the sequence diagram drawn for AlphaTargui (see appendix 1). We also choose to write the test cases before writing the code (Test driven development with a good overview?).

Before finding variability points we implemented a throw of a die as shown in paragraph 5.2.3. A variability point is found in move() in StandardGame.java:

```
            currentState = attackStrategy.moveAttack(tFrom, tTo);
```

The methods dieRolled() and givingUp() were added to StandardGame.java to implement 2 more variability points:

```
public boolean dieRolled(int dieValue) {
            currentState = attackStrategy.dieRolled(dieValue);
            return true;
}
public boolean givingUp() {
            currentState = attackStrategy.givingUp();
            return true;
}
```

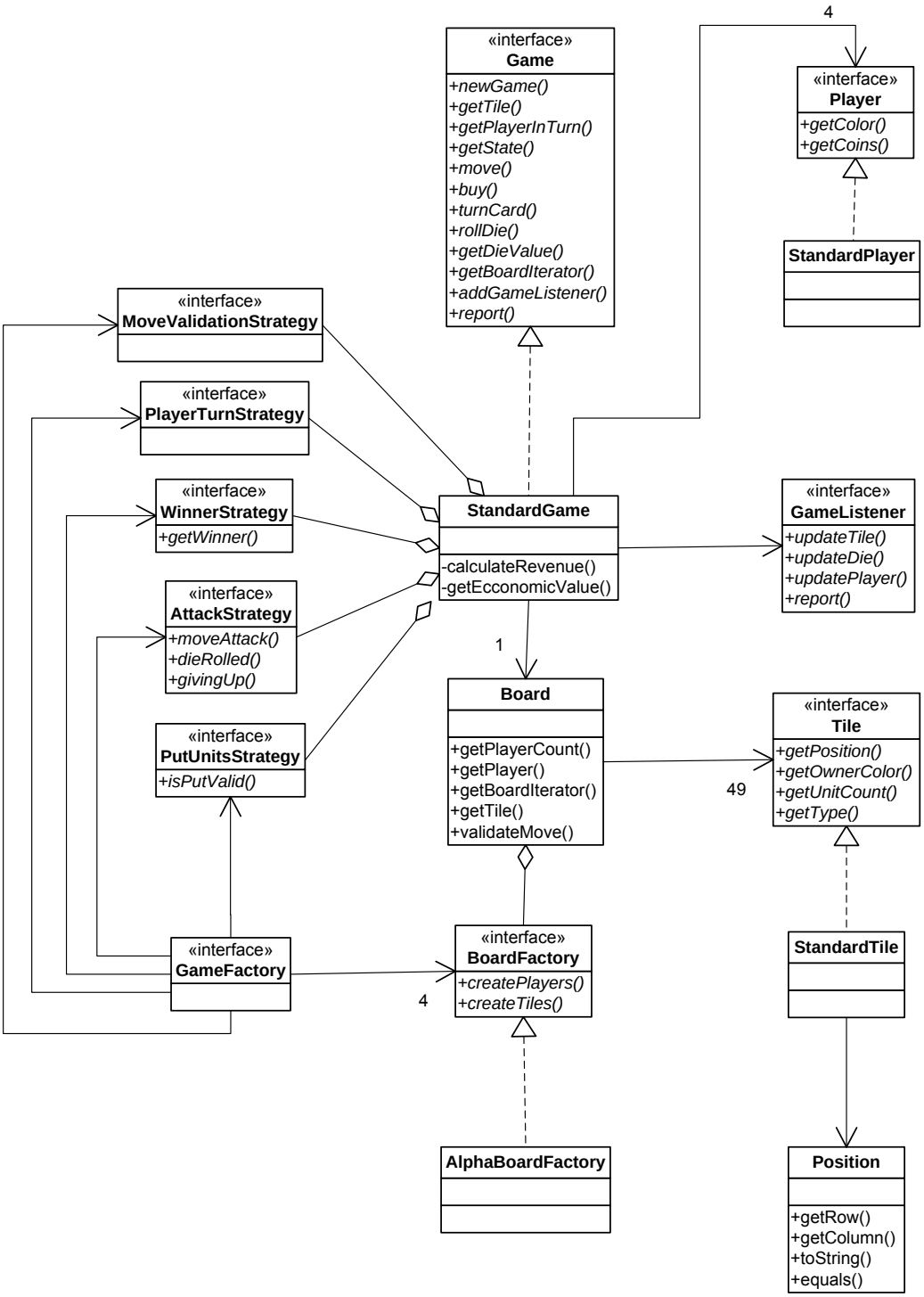
New source files: AttackStrategey.java (<<interface>>). Behaviour is delegated to AlphaAttackStrategy.java and BetaAttackStrategy.java.

New test file: TestAttackStrategy.java
To bring AttackStrategy under test control we wrote 3 test cases that cover a sequence for where the attacker is a winner, a sequence where the attacker is a looser and a sequence where the attacker gives up.

Yes, we can't say it too many times. Again we feel confident about implementing AlphaAttackStrategy when all test cases for AlphaTargui succeeded.

An alternative design proposal for the move/attack actions - introducing a new pattern - is presented in paragraph 5.4. We have been warned about switch creep etc. But what about pattern creep? We believe a parametric solution for the move/attack states is suitable, because the code isn't so comprehensive (the numbers of source code lines are small). If the code becomes more comprehensive (for instance when introducing new states) the state pattern presented in paragraph 5.4 should be implemented.

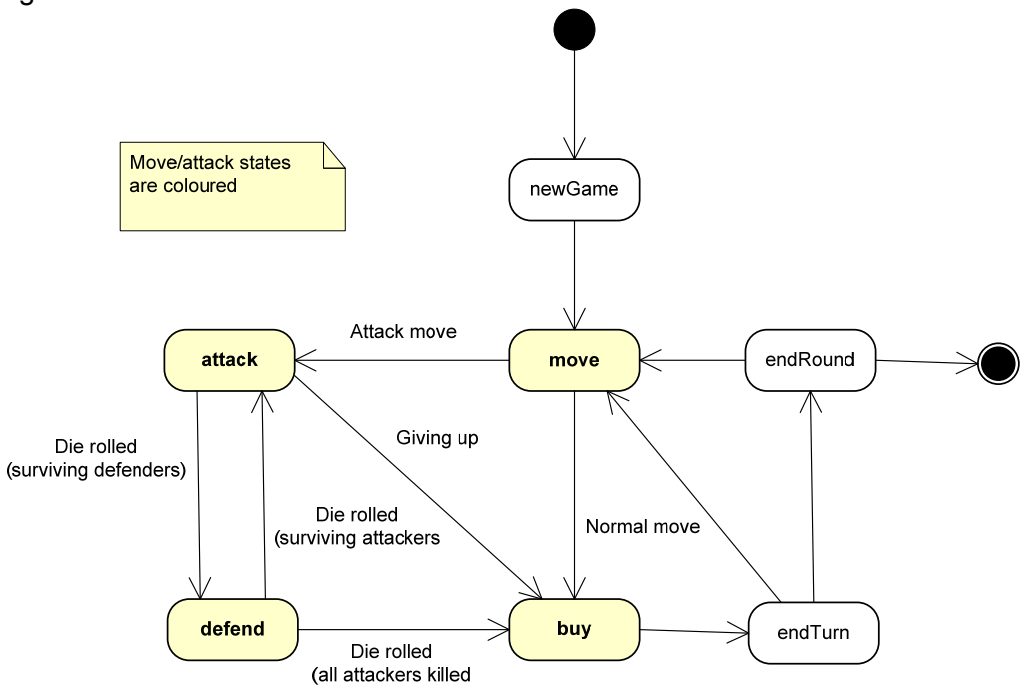
5.3 Class diagram for BetaTargui



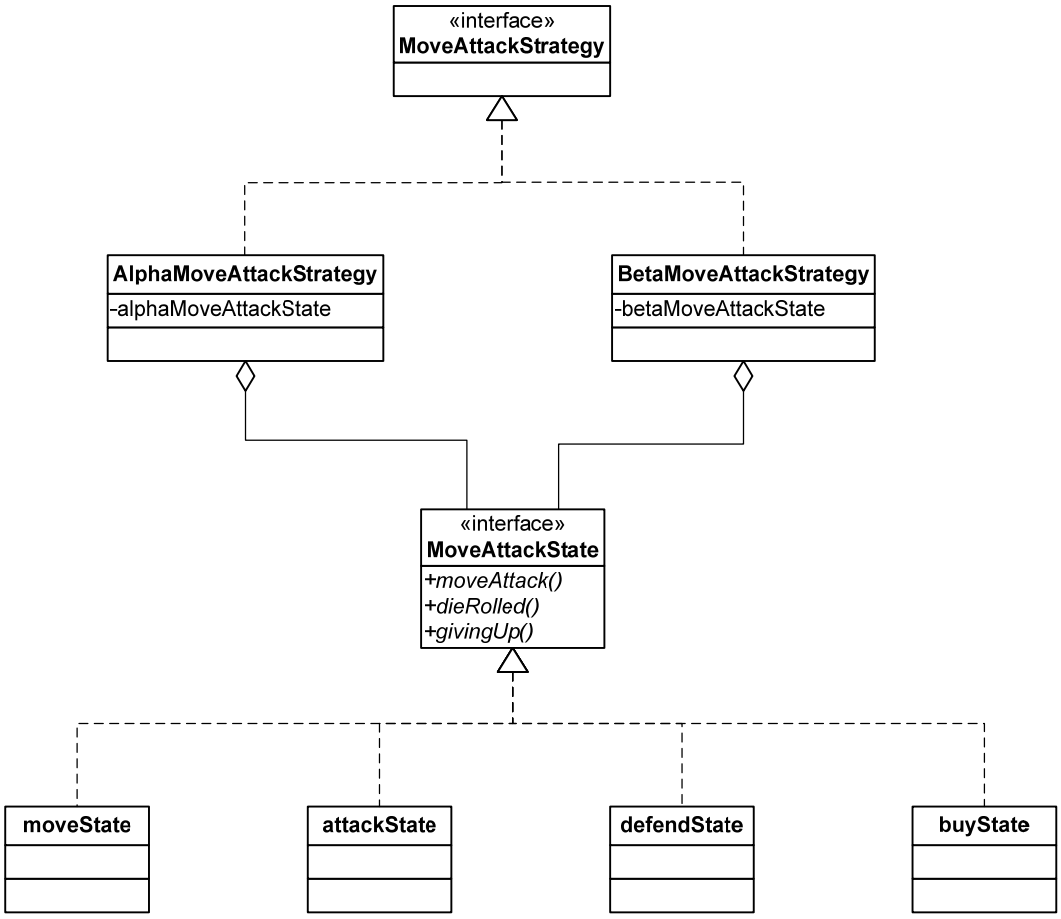
5.4 Alternative design proposal for move/attack actions

An obvious conclusion is to increase the responsibility of the AttackStrategy to include normal move. Then all move and attack actions are handled by the same strategy pattern. A name for the new strategy could be MoveAttackStragety.

A further consideration is to implement at state pattern for the move/attack actions. The state diagram is shown below.



Implementing a state pattern will result in class diagram for MoveAttackStrategy as follows.



Implementation of the state pattern will result in 5 news files: MoveAttackState.java, MoveState.java, AttackState.java, DefendState.java and BuyState.java.
MoveAttackState act as State role in the move/attack state pattern while the other 4 files implement the state specific behaviour.

OBS! Code for the alternative design proposal is only delivered in skeleton form.

```
public interface MoveAttackStrategy {
    boolean moveAttack(Tile tFrom, Tile tTo);
    boolean dieRolled(int dieValue);
    boolean givingUp();
}

public class BetaMoveAttackStrategy implements MoveAttackStrategy {
    public final static MoveAttackState STATE_MOVE = new MoveState();
    public final static MoveAttackState STATE_ATTACK = new AttackState();
    public final static MoveAttackState STATE_DEFEND = new DefendState();
    public final static MoveAttackState STATE_BUY = new BuyState();
    private MoveAttackState moveAttackState;

    public BetaMoveAttackStrategy() {
        moveAttackState = STATE_MOVE;
    }

    public boolean moveAttack(Tile tFrom,Tile tTo) {
        return setMoveAttackState(moveAttackState.moveAttack(this));
    }
    public boolean dieRolled(int dieValue) {
        return setMoveAttackState(moveAttackState.dieRolled(this));
    }
    public boolean givingUp() {
        return setMoveAttackState(moveAttackState.givingUp(this));
    }

    private boolean setMoveAttackState(State newState) {
        moveAttackState = STATE_ATTACK;
        return false;
    }
}

public interface MoveAttackState {
            State moveAttack(MoveAttackStrategy context);
            State dieRolled(MoveAttackStrategy context);
            State givingUp(MoveAttackStrategy context);
}

public class AttackState implements MoveAttackState {

    public State moveAttack(MoveAttackStrategy context) {
        // moves are not expected in this state
        return null;
    }

    public State dieRolled(MoveAttackStrategy context) {
        State nextState = State.defend;
        return nextState;
    }

    public State givingUp(MoveAttackStrategy context) {
        return State.buy;
    }
}
```

6 DeltaTargui

6.1 New requirement: Randomized board

6.1.1 Analysis

In DeltaTargui some new requirements has arose. Amongst them is a requirement of creating a randomized board instead of the predefined board from AlphaTargui. For this change of requirements, an analysis is made to help determine the right way of implementing the new requirements.

It is noteworthy, that this requirement actually is a change of a previous defined requirement. The requirement is therefore considered as an addition to a requirement defined in the past – the new requirement is a variant of an older requirement.

Now that is clear, that the new requirement creates a variability point in our system, we sought out to find the best way of implementing the new requirement. For implementing the new requirement in a safe manner, we will use some principles for achieving a flexible design. The principles are:

- Change by addition, not modification. The code we produce for fulfilling the new requirement should be an extension of the existing code. The AlphaTargui code is considered stable and no further modifications should be made to the code base. A good reason for is that DeltaTargui is only one of the variants of the AlphaTargui code base. BetaTargui will also rely on the AlphaTargui, so if the AlphaTargui code base is changed, BetaTargui will surely run into trouble.

- Keep code open for extension. In the future, someone might want to create a variant over DeltaTargui – a variant of the variant. The DeltaTargui code should be implemented so it is possible to extend it without making modifications to the DeltaTargui code base.

Now that we setup some of the goals with the new variant, we will identify the variability points in the implementation using the 3-1-2 process.

- 3 – Encapsulate what varies. In this requirement it stands clear, that it is the layout of the board that varies. In AlphaTargui an abstract factory has been introduced to ease composition of the board. This factory is named BoardFactory and the responsibility is described as:

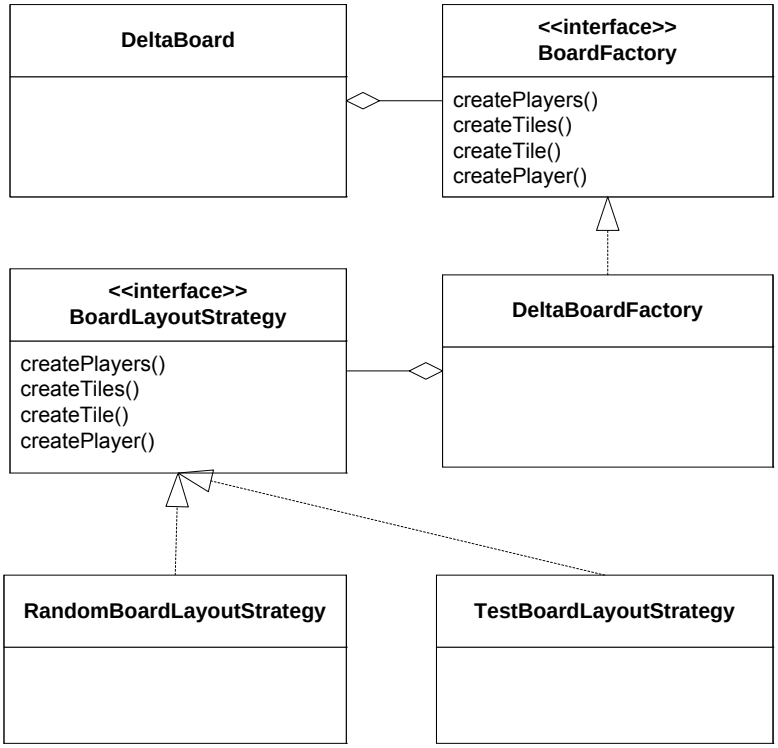
```
public interface BoardFactory {

    Player[] createPlayers();

    Tile[][] createTiles();

    Tile createTile(TileType tt, PlayerColor pc, int r, int c, int unitCount);

    Player createPlayer(PlayerColor pc, int unitCount);
}
```

In AlphaTargui, we created an implementation of the BoardFactory named AlphaBoardFactory. The implementation placed all tiles on the board in a predefined way. The responsibility for creating the board was implemented directly in the AlphaBoardFactory.

1 – The DeltaBoardFactory should not be directly dependant on an implementation of the randomized board. Therefore, we chose to introduce the BoardLayoutStrategy interface. The strategy removes the responsibility of the board layout from the BoardFactory and delegates it to the chosen strategy.

2 – By letting the DeltaBoardFactory composite the tiles with help from the BoardLayoutStrategy, we make sure that it will be possible to e.g. change the board on runtime – e.g. there is not compile-time bindings as we only assume an implementation of the BoardLayoutStrategy. This gives us very loose coupling between the factory and the implementation.

In DeltaTargui we have chosen to make an implementation of the BoardFactory, DeltaBaordFactory and let the factory create the players and the board. The creation of the tiles is delegated to the BoardLayoutStrategy. For the DeltaTargui, the createTiles() is implemented in the RandomBoardLayoutStrategy. The method creates the tiles and places them randomized on the board. A snippet of the design is outlined below:



In DeltaTargui we could have chosen to implement the new requirement directly in a realization of the BoardFactory interface named DeltaBoardFactory. This would have made reuse of a certain layout for the board harder as it is hardcoded into the DeltaBoardFactory. Upon creation of the strategy for the board layout, it is also possible to create a strategy which makes it easier to test the board layout is as expected.

The code snippet for the DeltaBoardFactory is below:

```
/**
 * This implementation of the BoardFactory supports correct
 * placement of the different tile types on the board.
 * The tiles are positioned according the specification.
 */
public class DeltaBoardFactory implements BoardFactory {

    private BoardLayoutStrategy boardLayoutStrategy;

    public BoardLayoutStrategy createBoardLayoutStrategy() {
        return new RandomBoardLayoutStrategy();
    }

    public Player[] createPlayers() {
        return boardLayoutStrategy.createPlayers();
    }

    public Tile[][] createTiles() {
        return boardLayoutStrategy.createTiles();
    }

    public Tile createTile(TileType tileType, PlayerColor playerColor, int row, int column, int unitCount) {
        return boardLayoutStrategy.createTile(tileType, playerColor, row, column, unitCount);
    }

    public Player createPlayer(PlayerColor playerColor, int unitCount) {
        return boardLayoutStrategy.createPlayer(playerColor, unitCount);
    }
}
```

Upon implementing the strategy for the layout of the board we have noted some benefits and liabilities upon using the above mentioned design.

Benefits:

1. Easy code extension. It is easier to extend the functionality of the variant as change by modification is used.

2. Encapsulation of responsibility is very clear as each code block only has well-defined responsibility.

Liabilities

1. Bloat of interfaces and implementations. Suddenly, it becomes very obvious why a good naming convention of the interfaces is needed. It does not take long before the code mass seems overwhelming.

2. (Traceability) One might say that tracing each method call becomes difficult as the call is delegated on. A good class diagram is needed for this purpose.

3. Difficult to explain to “the uninvited” – for a person new to the project it might be difficult to get an overview of the code.

6.1.2 Implementation

DeltaBoardFactory implements the algorithm defined in the project description. The algorithm is stated as:

1. The saltmine is positioned in the center of the board.

2. The different types of tiles are placed randomly on the board. The number of each tile type is predefined.

3. Each corner tile is replaced with one of the four settlement tiles. The position is as follows:

    1. Red settlement – Upper left corner (0, 0).

    2. Green settlement – Upper right corner (0, 6).

    3. Blue settlement – Lower left corner (6, 0).

    4. Yellow settlement – Lower right corner (6, 6).

To take small steps and keep focus, the above steps are implemented in multiple iterations. In each step a requirement is implemented.

The test list contains a test that reads: “Tile positions matches specification”. This test definition is not very concrete and the test is therefore broken down into smaller tests, who match each of the three identified iterations.

6.1.3 Position saltmine

We need to position the saltmine in the center position of the board according to the specification. For this purpose we add the test case 'testSaltmineCenterPosition' to the newly created TestDeltaBoard class. Testing for the position of the saltmine is simple:

```
/**
 * Test that the Saltmine is in the center position (3,3)
 */
@Test
public void testSaltmineCenterPosition() {
    // Get tile at center position
    Tile tile = board.getTile(new Position(3,3));
    // Get tile type
    TileType tileType = tile.getType();
    // Assert it's the Saltmine
    assertTrue(tileType.equals(TileType.Saltmine));
}
```

6.1.4 Position tiles randomly on board

In AlphaTargui, we created an instance of the BoardFactory with fixed positioning of the tiles. We generated test cases for the fixed positions.

Now, we have to generate random positions for the tiles, who we add to the board. Compared to the AlphaTargui, this serves a new problem. In AlphaTargui, a tile has the responsibility of knowing its own position. This means, that the board does not have any knowledge about where each tile type is positioned. The board can determine the type of the tile, position, owner and units on the tile by using the tile interface.

When we need to add tiles randomly to the board, we should not place a tile on the board, where a tile previously has been positioned. This is only the case when placing the settlements.

6.1.5 Lesson learned: Read specification carefully!

When implementing this requirement, the first approach was to generate the positions, available for the tiles that should be positioned. Generating the positions was fairly simple with a double loop:

```
Position position;
for (int i = 0; i < 7; i++) {
    for (int j = 0; j < 7; j++) {
        position = new Position(i, j);
    }
}
```

This loop created all the positions on the board. The positions were held in a collection, where each position was removed and assigned to a tile. Creating the tiles stated in table 2.1 in the requirements specification was simply a question of looping the number of times according to each specific tile and create the tile.

The created tiles were held in a collection. This collection was iterated an assigned a position from the available positions.

Although the algorithm for filling the board, there was not paid so much attention to the sequence of the steps, hence they were altered to the below mentioned for ease of implementation.

a. Place the 'Saltmine'

b. Place the settlements on the predefined positions.

c. Place the randomized tiles.

There were 49 available positions. Suddenly the createTiles() method started throwing IndexOutOfBounds exceptions. This was strange; because the test cases created for probing the number of each tile type was not revealing any defects. The correct number of tiles existed. Debugging the loops and reading the table again didn't reveal anything.

OK, back to good old system out. Every time a tile was created, a line with a description of the tile was printed. Before assigning positions to the tiles, the line count was 53. Not 49 as the available positions. Summing the numbers in table 2.1 also gave 53.

Reading the algorithm for populating the board revealed the defect; the settlements were to replace the four corner tiles, meaning that four random tiles were discarded from the game. Implementing this was thought to be simple, but later proven otherwise. As we removed positions from a collection upon tile creation, these positions were used and no longer available. How to reassign the pre-defined positions for the settlements?

A new solution was made: We created a simple deck interface with the responsibility of creating a deck of tiles according to the DeltaTargui specification.

```
public interface Deck {

    public Tile getTile(Position position);
    public void shuffleDeck();
    public boolean isEmpty();

}
```

Internally, the deck implementation (DeltaDeck) consists of stack, which is given the tiles for the DeltaTargui specification.

A new implementation of the Tile interface was made (DeltaTile), where it's possible to assign a position to a tile after creation. Randomness was made by using the Collections.shuffle method in Java. This method applies standard random behaviour. The original object-oriented thinking is very much applied to this implementation. The deck is seen as simulation of a part of the physical world.

Another advantage of the new deck interface is that responsibility for creating the deck is separated out from the DeltaBoardFactory.

What we learned from this episode are:

a. Read the specification, even small changes can mean a lot to the architecture.

b. Making mistakes might lead to better software, as we were forced to think the things over again.

c. Place test cases at the “right level”. In this case it was good that we tested for the amount of each tile type. This eventually led to a reveal of a defect. If we had tested for the amount of tiles on the entire board, this would probably not have happened.

d. Test cases make code evolve and vice versa. The test cases we initially created revealed a defect. But as the code changed, some of the test became outdated. It’s not possible to test for a specific number of tiles, when some of tiles are randomly replaced. Though, the test cases are OK, when they are run before the tiles are replaced.

e. Keep test cases isolated.

f. Refactor step in TDD is important, as the “gold” is here. The reflections made here are very important for your code and often provides efficient code changes.

6.1.6 Lesson learned: Stable code base is needed!

Developing of the DeltaTargui was begun before the AlphaTargui code base was stable. We had chosen to make a copy of the AlphaTargui source and use the AlphaTargui code base for developing the new variant. Development of the new variant begun, but the interface of the BoardFactory had methods that changed signatures parallel to development of the DeltaTargui. So, a new feature was needed from AlphaTargui and the source code corresponding to AlphaTargui was updated from Subversion. Suddenly, some of the methods of the BoardFactory returned tiles in another way.

The solution was to be “interface-adherent” and comply with the specification posed by the interface.

This caused only minor annoyance, but looking at how few source files we have been developing in this project we can easily figure out what pain it might cause in larger projects.

7 SemiTargui

When we begun Semi-Targui we looked at the level of change and decided that the BetaTargui had the most updates. This is an issue because Beta and Delta, as specified in the assignment, was developed in parallel based on Alpha. They will therefore most likely not have made the same updates of the interface. Alpha is naturally still supported in both. This may be seen as an inheritance hierarchy, where Alpha is the base, Beta and Delta is implemented based on Alpha and Semi is the combination of Beta and Delta; Diamond of death, as shown in Figure 1.

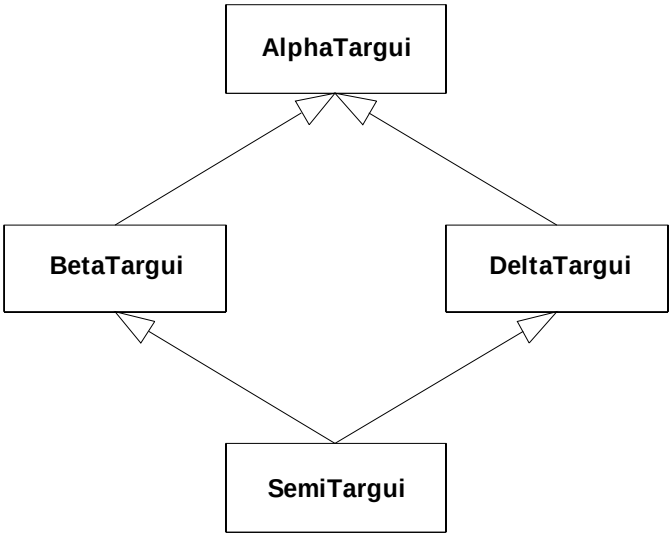


Figure 1 Merging the products

Naturally this is not inheritance, but combination. As we combine the three we are lucky that they do not overlap more than one place; they both have a new winner strategy. Luckily it is the same winner-strategy they have implemented, so we can simply choose one, and as we are choosing to base it on Beta, we choose this winner strategy. The interfaces that have to be included from Delta relate to the setup of the board, and these are moved from the Delta project to the Semi project.

We then begin the merging process.

1. First we realize that the Alpha, Beta and DeltaGame are basically identical, and we can therefore create a StandardGame which is simply configured. The class is moved to the standard package.

2. The same is true for Board, as the configuration from Delta happens in the factory and we create StandardBoard. The class is moved to the standard package.

3. We decide to rename AlphaBoardFactory to StaticBoardFactory so it more indicates what it creates and moved it to the factory package.

4. We rename DeltaBoardFactory to RandomBoardFactory for the same reason and are moved to the factory package.

5. AlphaPutStrategy becomes SettlementOnlyPutStrategy and is moved to the strategy package.

6. BetaPutStrategy becomes AllTilePutStrategy and is moved to the strategy package.

7. The StandardMoveValidationStrategy is used everywhere so it is moved to the standard package.

8. The AlphaAttackStrategy becomes SimpleSttackStrategy and is moved to the strategy package.

9. BetaAttackStrategy becomes DieRollAttackStrategy and is moved to the strategy package.

10. AlphaWinnerStrategy becomes SaltMineWinnerStrategy and is moved to the strategy package.

11. BetaWinnerStrategy becomes RevenueWinnerStrategy and is moved to the strategy package.

We now create the SemiGameFactory and combine the following:

1. A StandardBoard with a RandomBoardFactory

2. An AllTilePutStrategy

3. A StandardMoveValidationStrategy

4. A DieRollAttackStrategy

5. A RevenueWinnerStrategy

Here you truly see the strength of the compositional design, as the combination of the projects and the creation of a new project which uses the best of the combined worlds took all of 15 minutes. Something even a project manager can understand the advantage of.

7.1 Updates

There are a few matters which may be optimized. We are not entirely happy with the design of the Game – GameFactory interdependency and the extra methods on Game (like getBoard). This derives from the fact that strategies needs information from not only Game but also other strategies. This has for the getWinner been solved by supplying the round-count as an argument, but it might not be all winner strategies that need this.

That the strategies need access to the Game is unavoidable, and also not a huge deal, but populating the Game interface with methods to service the strategies are not optimal. Luckily there is a solution for this; allow the strategies to reach each other.

This can be done in several ways (static members, arguments, etc.), but there is also a great pattern which supports this sharing; the Repository pattern. This pattern has other advantages, like runtime replacement of strategies and replacement of Repository implementation for testing purposes (or to use different means of storing the objects).

We therefore redesign the Game implementation to take a GameRepository rather than a GameFactory, and only access the needed strategies through this interface. The GameFactory is kept, as it is used to populate the GameRepository. As the repository only operate on interfaces and simply return the object values, we can create a StandardRepository that fits for all intents and purposes (under the given interface and present requirements). This is also the reason why the “never talk to strangers” principle may be bypassed here, because that is the very idea of the pattern. The new design may be seen in Figure 2

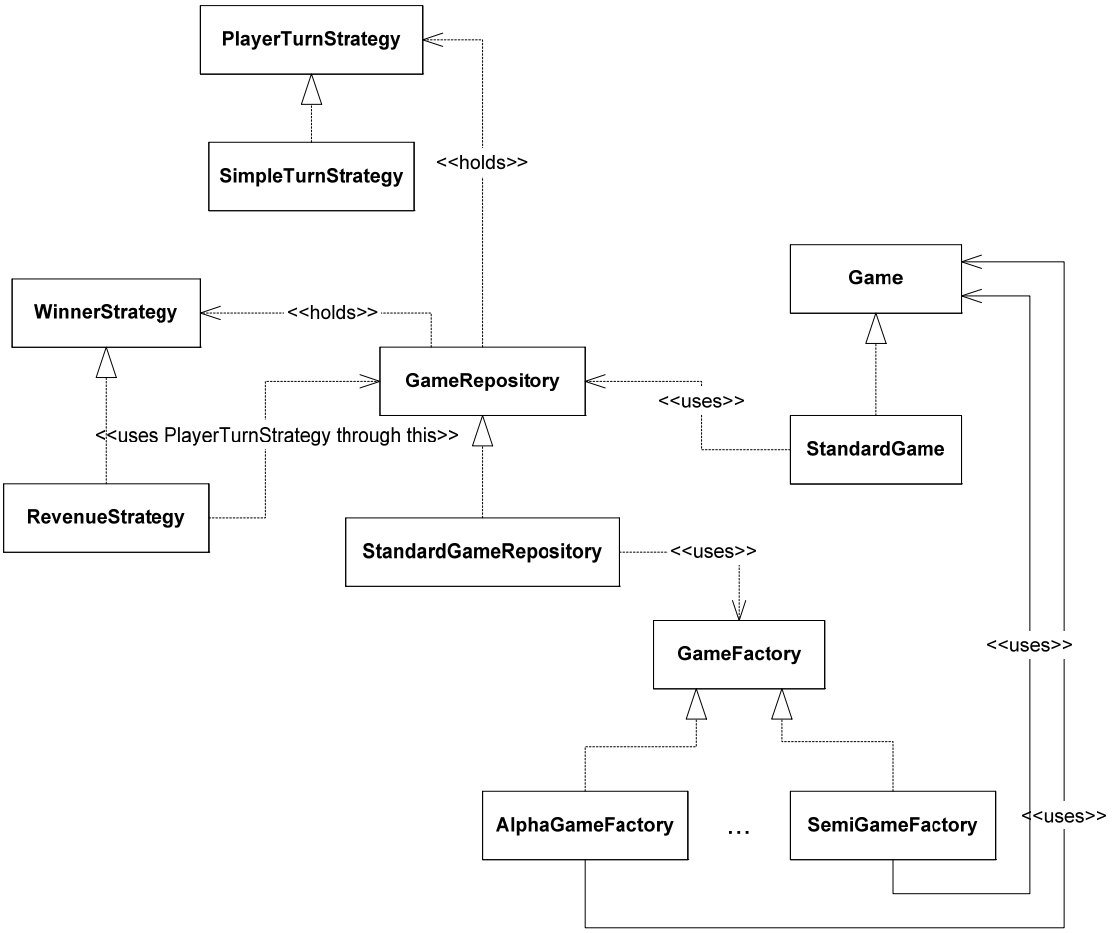


Figure 2 GameRepository class diagram

As it may be seen the GameRepository must have the Gamefactory set. This is due to the fact that the GameFactory still need a reference to Game and the StandardGame

takes a GameRepository as a constructor argument. Some of the dependency arrows are left out (like the RevenueStrategy also knows the Game interface) for readability.

8 Assignment 4B

Creating an architectural prototype may have more than one purpose

1. Determine if a selected architecture meets the desired quality attributes.

2. Compare a number of possible strategies with each other based on how well they meet a number of quality attributes.

This assignment focus on comparing three different approaches to creating a distributed version of HotTargui. In order to compare the prototypes we have to have something to evaluate them against, and this is where quality attributes comes in.

First we need to define which quality attributes are of interest and their relative importance, and then the individual architectural prototypes can determine how well the given architecture meets the quality attributes before finally comparing the results.

As we do not have a stakeholder issuing requirements and helping us prioritise quality attributes we will instead focus on the advantages and disadvantages of the different architectures.

8.1 Peer to peer

The peer to peer architecture has certain advantages

1) Identical code executing on all location – no server or master-appointment required.

2) Possible increased performance (response-time) due to locally accessible data and validation.

3) Unlike server solution discovery is required.

4) Unlike hosted server all data must be replicated to all applications increasing requirement for application memory.

5) Poor scalability - As the replication must be done to all applications the communication-requirements increase linearly with the number of applications. The server and hosted server the communication is constant with increasing connections.

6) Simpler, as no server code must be written.

As we can see scalability is definitely not an advantage with peer-to-peer, yet as the number of players is fixed to a maximum of 4 this is not a huge problem. The peer-to-

peer solution has its justification in the fact that it is simple; no dedicated server application required, no appointment of a host, just the “simple” synchronization of data.

When creating an architectural prototype it must be decided which aspects of the behaviour to validate/evaluate, as there may be several. In the peer-to-peer network there are at least two distinct areas; discovery and synchronization. Another might be game-play, but it is no different from the server or hosted-server solution so it is not very interesting from a comparison point of view.

Even though the discovery mechanism is quite interesting we choose to focus on the synchronization mechanism. There are several discovery protocols and even commercial implementations available for purchase, e.g. UPnP discovery or Web Service discovery. There is an important difference between LAN and WAN discovery, which has to do with reachability. LAN discoveries (e.g. UPnP discovery) rely on LAN broadcasting mechanisms like UDP to notify interested parties of a newcomer to the network. This approach does not work on a WAN, as Firewalls and the sheer vastness of the network eliminates the broadcasting approach. For this reason a form of server-discovery is used, where the individual clients contact a central server to get a list of participants and also the receive notification about changes to the network layout. This approach is probably best known as the Napster-architecture.

In order to decide on discovery it is therefore important to determine the forms of use; Is the distribution of this game designed to be used on a LAN (e.g. 4 computers connected y a switch) or a WAN (e.g. 4 computers in different parts of the world connected by the Internet). As we have chosen to focus on the data synchronization and not the discovery for this architectural prototype, this issue can be postponed until later, as no matter how the discovery is done the outcome is the same; a list of addresses for the participants in the game.

We therefore design this architectural prototype on the premises that this information already exist.

To create the architectural prototype we need to identify the relevant parts of the code. As we deal with synchronization we need all the domain data, which consists of the board information as well as the game state information.

This information is collected behind the interfaces Game and Board. We now have to consider the design principles we wish to employ. We can synchronize all state information for all classes, including the strategy patterns, which, in some instances, also contain state information. We can also choose to simply perform the same moves on all connected applications, thereby having the state-information update independently of each-other, yet as the applications are identical the resulting states will be synchronized.

The difference between the two options is in the dependencies, and may be seen in the below figures.

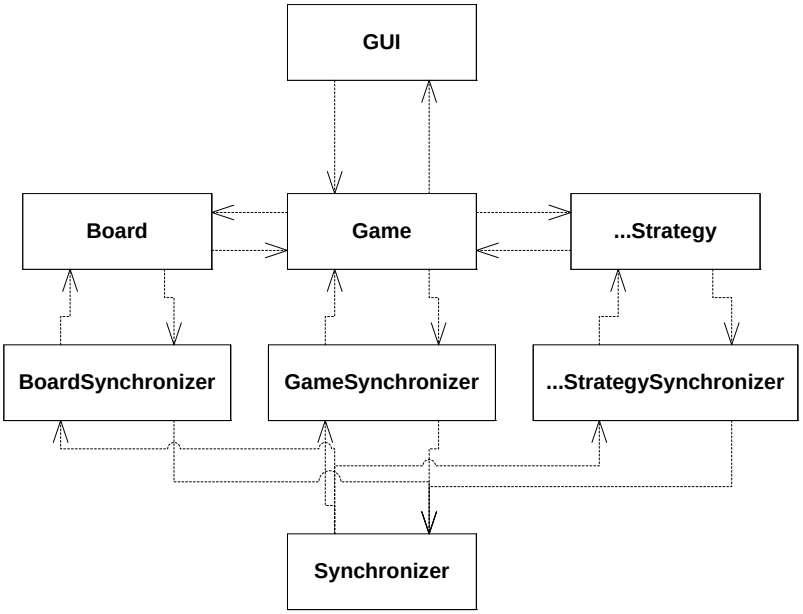


Figure 1: Data synchronization

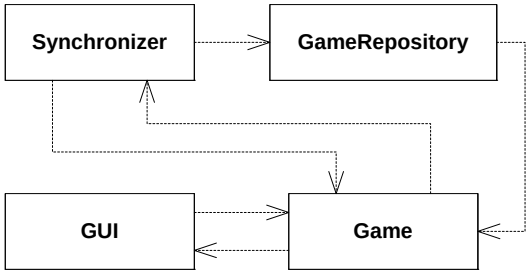


Figure 2: Action synchronization

Both approaches have advantages and disadvantages. The first, though it may seem more complicated, is actually more robust and simple to understand. When implementing data synchronization it is often beneficial to move the raw data values to a separate class.

This is not only an advantage of this, as it encapsulates the data, it also allows for replacing the storage from in-memory variables to a file or a database. This would make implementing a store and re-store functionality very simple allowing for a game to be paused and later picked up again. The disadvantage is that all data must be synchronized and that any change to the data must be evented through the game interface to any interested listeners. For this reason, and due to the fact that we have no requirement to store the game, we choose action synchronization.

Naturally action synchronization also has advantages and disadvantages. It relies on recreating the actions on all instances of the game, which may not always be possible. The game includes a die, which in its nature is unpredictable, so how would we reproduce the same die-roll on all applications? Luckily the die-roll has been abstracted away behind an interface for testing purposes, and due to the use of the repository

pattern we are able to replace the die-roll strategy at runtime to one where we can control the outcome. Upon inspecting the Die interface we realise that there is an even easier solution, as the Die interface allows for the setting of outcome directly on the interface, and no strategy-replacement is needed.

In order to create the architectural prototype we have to strip down the existing code to only include the absolutely necessary and only implement what is required to show that the solution works. We also have to determine what we wish to measure; performance, communication requirements, responsiveness...

As we know that the issue with peer-to-peer lies in its scalability we choose to look at communication through-put in order to determine how it rates compared to one of the other solutions; server or hosted server.

Implementing the GameNetworkDecorator may be done in many ways, yet as we are performing a given action on multiple destinations, one approach is to use the decorator pattern, which allows us to intercept all actions on the Game interface and pass them on to the remote locations, or rather pass on the valid moves, as the peer-to-peer solution has the advantage of local validation and does therefore not need involvement of other parties in order to determine validity.

The decorator pattern is implemented by creating a new implementation of the Game interface, which simply forward all calls to the normal implementation, but then perform some operation either before or after the call. In our case we want to perform a synchronization of an operation if it succeeds (and if it changes the state or layout of the game). The synchronization-calls should always succeed if they succeeded locally, as the layouts are always identical.

This allows us to distribute all commands, but it does not handle the reception of the command. Here another pattern comes in handy; the Proxy pattern. By keeping a proxy of the remote Game implementations it is possible to perform the same calls remotely as was performed locally. This is also where the replacing of the die-roll strategy comes in handy.

First we will implement the decorator pattern, which for the simple actions requires code like:

```
public boolean buy(int count, Position deploy) throws RemoteException {
  boolean res = game.buy(count, deploy);
  if (res) {
    Set<Game> coll = remoteGames.keySet();
    Iterator<Game> itt = coll.iterator();
    while (itt.hasNext()) {
      Game g = itt.next();
      g.buy(count, deploy); // No reason to look at return value
    }
  }
  return res;
}
```

For the rollDie it is a little more complicated, but still manageable, as shown here

```
public void rollDie() throws RemoteException {
  game.rollDie();
  int value = game.getDieValue();

  Set<Game> coll = remoteGames.keySet();
  Iterator<Game> itt = coll.iterator();
  while (itt.hasNext())
  {
      Game g = itt.next();
      GameRepository gr = remoteGames.get(g);
      Die ds = null;
      try {
        ds = gr.getDieStrategy();
      } catch (RemoteException e) {
        e.printStackTrace();
      }
      // First we actually roll the die to ensure propper state change
      g.rollDie();
      // The we manually override its value with the value we want
      ds.setValue(value);
    }
}
```

The above implementation does require certain things to hold true. The Die implementation must work in the manor described (a call to setValue will ensure that a subsequent call to rollDie will result in this value, thereafter the die functionality returns to normal (random).

Similar may be done for the Cards, yet as these are not part of the implementation it is not needed and we can simply ignore the call.

Now for the implementation of the access to the remote game implementations. Here we use the Java RMI registry to perform the calls on the remote Game instances. In order for us to do this it is required to name the instances and to have these names known at start-up. We choose the simplest possible solution and uses a command line argument to differentiate the instances when they are registered with the RMI registry, and as we define the four possible arguments as ”red”, ”green”, ”blue”, and ”yellow” they can be connected at start-up.

Naturally this requires that they are all connected before the system is running. This is handled in the architectural prototype by having the initiating code first register its objects and then continuously attempt to get the three remaining remote objects until it is successful and first after that allow the game to continue. This should ensure that all games will be initialised approximately at the same time (when the last application is started). Naturally another argument could be used to indicate the number of players, so we do not have to test with four players all the time.

To interfaces Game, Die and GameRepository has to extend Remote and all methods in the interfaces must throw RemoteException. We could choose to update the existing code, but this would divert attention away from our purpose – the architectural

prototyping of the peer-to-peer solution. We therefore design test-stubs for Game, Die and GameRepository, which only implements what is necessary to validate the networking functionality. These test-stub implementations must naturally implement the interfaces, but for java RMI to use them must also extend UnicastRemoteObject. Then they have to be exposed, and this is done in the GameInitializer code. The value types involved must also be updated to be Serializable (e.g. Position), and this is done. Player and Tile are interfaces, so they could also be stubbed, yet as none of the implementation requires tiles or players to be retrieved across the network they are simply ignored (remove from the architectural prototype code).

As the registration in the Java RMI registry is rather expensive we implement the test not as a true unit-test, but as a transition-tour. The difference between a unit test and a transition-tour lies mainly in the notion that the environment is not setup from scratch every time, rather a test-case manoeuvres the code back to its origin. An example of this may be testing a large SQL database. Instead of the following sequence (yes, it is not correctly formulated test-case names ☺):

1. insertionIntoDatabase
    a. Create SQL database
    b. Inserting an item in database
    c. Validate that item was inserted
    d. Delete SQL database
2. renamingInDatabase
    a. Create SQL database
    b. Setup SQL database (insert item)
    c. Rename item in database
    d. Validate renaming
    e. Delete SQL Database

We may optimise it by not deleting the database, but rather returning it to its origin:

1. Initial Setup
    a. Create SQL database
2. insertionIntoDatabase
    a. Inserting an item in database
    b. Validate that item was inserted

c. Remove item from database

3. renamingInDatabase
    a. Setup SQL database (insert item)
    b. Rename item in database
    c. Validate renaming
    d. Remove item from database
4. Final teardown
    a. Delete SQL Database

Now this is an optimization as the database is only created once, which is the resource-expensive part of the test. The reason it is called a tour can be just be hinted in the test cases, as we test more than just what we mention – we also test remove. By making the order of the test-cases of value it becomes even more apparent, and further optimization can be done:

1. Initial Setup
    a. Create SQL database
2. insertionIntoDatabase
    a. Inserting an item in database
    b. Validate that item was inserted
3. renamingInDatabase
    g. Rename item in database
    h. Validate renaming
4. Final teardown
    d. Delete SQL Database

This naturally goes against the unit-testing principles, yet as it is a transition-tour and not a unit-test it is acceptable. The idea of a transition tour is defining a sequence of events which tests all transitions in the code, which for black-box testing basically means systematic testing of the interfaces (remembering to differentiate on input, output and interdependencies). The transition tour is not designed for black-box testing, but for white-box testing and it is meant to drive class or collection of classes to all its states using all possible transitions – at least if you want 100% transition coverage. Our requirements for the architectural prototype do not specify anything about coverage, so

this is not a goal in our case – we are focussing on the synchronization. A call to one game must be performed on all games.

We therefore set up a test list (transition tour)

1. Calling newGame on one Game will result in a call to newGame on all other games
2. Calling move on one game will result in identical move on all other games.
3. Calling invalid move on one game will not result in any activity on the other games.
4. Calling buy on one game will result in identical buy on all other games.
5. Calling invalid buy on one game will not result in any activity on the other games.
6. Calling rollDie and getDieValue on one Game will give same value as all subsequent calls to getDieValue on all other games.

As the get-methods are only called locally, they are not interesting except to test the decorator pattern, but as this is not of interest here we stop at these six tests.

8.1.1 Conclusion

As mentioned earlier the architectural prototypes could be used to compare solutions, yet due to time constrains we do not have sufficient data to perform the comparison. For this reason we change the purpose of the architectural prototype to be a proof-of-concept for the peer-to-peer solution; how few changes, if any, is required in the current interface to service a networking solution?

As it can be seen from the architectural prototype it was possible to implement the peer-to-peer solution without any change to the interfaces, which is naturally a big advantage. It can also see that there are iterations over the number of players – 1, which illustrates the poor scalability quite well. The chosen solution of synchronizing actions has very limited data-chunk sizes, and it is therefore not a big problem with respect to bandwidth.

We used naming convention and the Java RMI registry for discovery, yet we may just as well have used a UDP broadcasting (LAN), UPnP discovery (LAN) or a naming service or server (LAN/WAN). We could also have made it purely manual, where the players would have to exchange addresses by other means (word-of-mouth (LAN), telephone (WAN)). Again, as this is an architectural prototype we chose what was the simplest with sufficient realistic characteristics, which was Java RMI. Alternatives is CORBA IIOP or DDS (Open DDS being a great free implementation), DDS being a publish-subscribe middleware that could easily have been used to distribute the actions. The publish-subscribe system would actually be the most suitable, as it allows for multicasting. Multicasting allows for sending a message to a group of subscribers with a single command. This is similar to the UDP multicast, which is often used as the underlying communication backend (often in a reliable version, unless it is a fire-and-forget application).

The architectural prototype developed in this section show quite clearly that it is relatively simple to extend the Game with networking abilities using Peer-to-Peer communication, and that a maximum player-count of 4 is no hindrance on a LAN, and that both commercial and open-source solutions exist for discovery. Based on the simplicity with which the peer-to-peer solution may be made to work, it is deficiently a strong possibility.

8.1.2 Future architectural prototypes

Naturally there are many other aspects of the networking design that may be analyzed, yet these do relate to the difference between peer-to-peer, hosted server and domain server and is therefore not included in the above analysis. A few relevant possibilities are mentioned here.

1. Discovery

   As mentioned there are several both commercial and open source solutions, proprietary and manual, and these should be evaluated against each other. They naturally have to be held against the proposed range of the networking (LAN or WAN), which is not defined as present.

2. Usability

   In the present architectural prototype no consideration has been taken into usability. Any location may perform a move at any time, which means that there is no way of enforcing that only the person playing red is moving and buying for red. A solution would be to start the application in a networking-mode where a given application can only move certain colour(s) via the GUI. How well this, or other possibilities, works should be evaluated.

3. Configurability

   At present it is simply assumed that the applications running at the different locations are identically configured. This is a big problem if they are not, e.g. if an AlphaTargui configuration played against three SemiTargui configuration. It is possible to build in a configuration validation in the discovery or perhaps in a post-discovery handshake, and these possibilities could be evaluated.

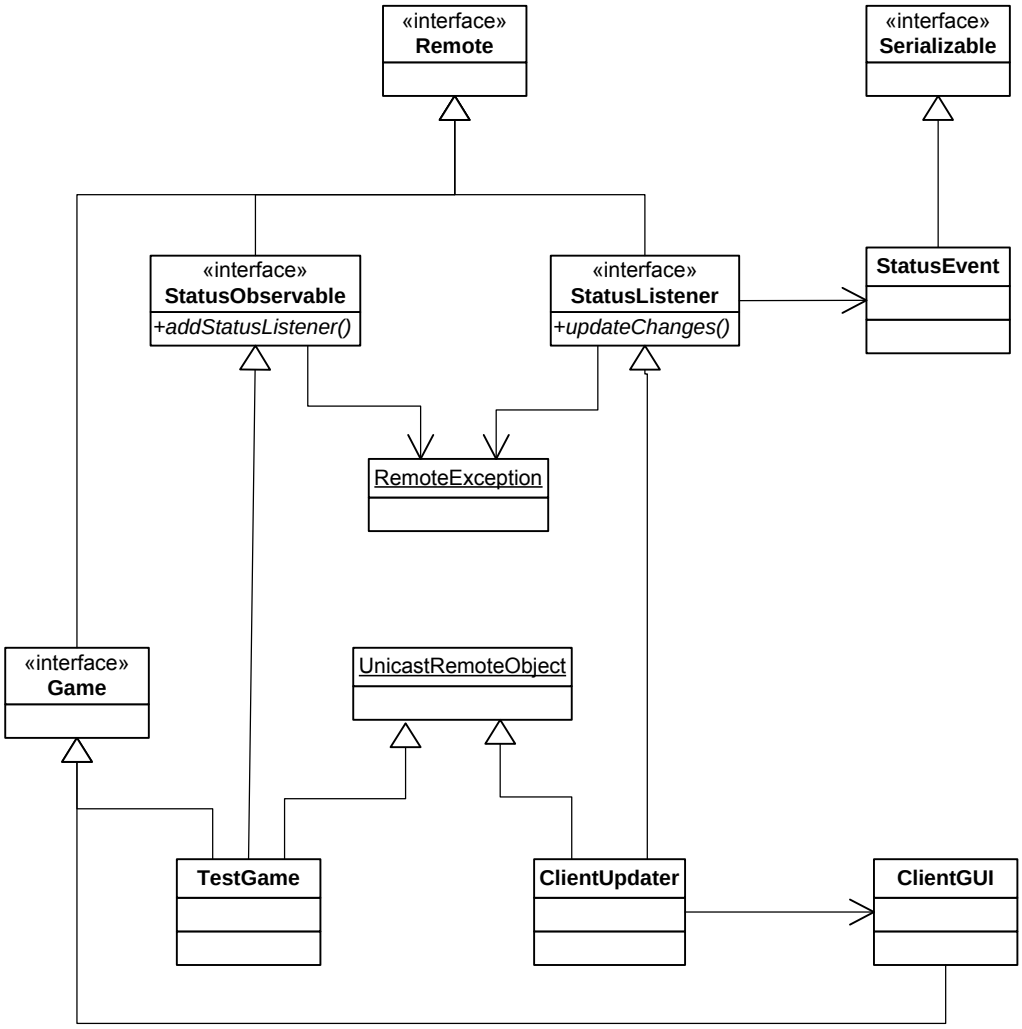
4. Security

   As this game is designed for good clean fun, and should be played by gentlemen such considerations are naturally of lesser importance, but at present there is no security against someone intercepting, preventing or altering the actions during synchronization. This could be a problem if more than an enjoyable parsing of time is at stake, and possible solution (e.g. CAs and digital certificates for authentication, encryption for confidentiality, signing actions for authenticity, etc.). The different solutions and implementations should be evaluated with respect to the desired level of security.

8.2 Domain Server

Unlike peer-to-peer networks, where network information is uniquely decentralized, the network information stored on a centralized file server PC is made available to tens, hundreds, or thousands client PCs. A client-server network is capable of handling more amount of information flow that a peer-to-peer network might.

Below we have sketched a class diagram for a distributed client-server system based on RMI for HotTargui:



8.2.1 Propagation of server state changes

Propagation of server state changes to the clients is implemented with an observer pattern.

The StatusObservable interface (the subject role) enables an Observer/Listener to be added and is exposed by the addStatusListener method.

In order to expose an interface on the network using Java RMI the interface must extend the interface Remote, and all methods of the interface must throw the RemoteException.

This means that the StatusObservable looks like this:

```
public interface StatusObservable extends Remote {
  /** Add a status listener to this instance */
  public void addStatusListener(StatusListener listener) throws
RemoteException;
}
```

The StatusObservable needs to be exposed globally, and this is done by calling Naming.rebind supplying the location of the registry and the name of the object. Something like:

```
clientGUI cGUI1 = new clientGUI();
try
{
  StatusObservable so = (StatusObservable)cGUI.getGame();
  // Expose game class
  Naming.rebind("//" + host + "/" + playerColor + "HotTargui", so);
}
catch (exception-classname variable-name)
{
  handler-code
}
```

On the other side a previously exposed object may be retrieved by calling naming.lookup. Something like:

```
TestGame tG1 = new TestGame();
try
{
  StatusObservable so = (StatusObservable)Naming.lookup("//" + host +
    "/" + playerColor + "HotTargui");
  so.addStatusListener(tG1.getStatusListener());
}
catch (exception-classname variable-name)
{
  handler-code
}
```

The StatusListener interface (the observer role) enables a StatusObservable to event back to the observer/listener (callback). This interface is passed by reference in a networked call (addStatusListener).

```
public interface StatusListener extends Remote {
  /** invoked whenever a game changes state. */
  public void updateChanges( StatusEvent event ) throws
RemoteException;
}
```

The StatusEvent class, which is passed as an argument to the updateChanges method of StatusListener, contains a value for State. Parsing an argument by value is done by letting the class implementing the Serializable interface:

```
public class StatusEvent implements Serializable {
  public StatusEvent(State state) {
    this.state = state;
  }
  /** the state of the game */
  public State state;
}
```

ClientUpdater implements StatusListener on the client site and receives the state changes.

To allow interfaces to be visible on the network, they must be implemented and the instance added to the global registry. In Java RMI the server may be generated using reflection and it is therefore enough to have the implementing class to extend the class UnitcastRemoteObject, which is a kind of generic server proxy stub.

This means that the ClientUpdater looks like this:

```
public class ClientUpdater extends UnicastRemoteObject implements
StatusListener {
  private State gameState;
  public ClientUpdater(State gameState) throws RemoteException
  {
    super();
    this.gameState = gameState;
  }

  public void updateChanges(StatusEvent e) throws RemoteException {
                      //To do
  }
}
```

This constructor just invokes the superclass constructor, which is the no-argument constructor of the Object class. Although the superclass constructor gets invoked even if omitted from the ClientUpdater constructor, it is included for clarity.

8.2.2 Invoking of game methods from ClientGUI

To call game methods like rollDie() from ClientGUI it need a remote reference to server object.

```
public class ClientGUI extends JFrame implements Game {
}
```

This declaration states that the class implements the game remote interface and therefore can be used for a remote object.

Letting ClientGui implementing the game remote interface is not a good idea – not only because game.getState() conflicts with getState() in java.awt.Frame – it is just not good design. A Façade pattern might be a good solution - or if it should be more advanced - a Model-View-Controller pattern.

8.2.3 Implementation of architectural prototype

To create the architectural prototype we stripped down the code to domain data only, which consists of board and game state information. The data is collected behind the interfaces Game and Board.

New domain data files (StatusEvent.java, StatusListener.java and StatusObservable.java) are located in hottargui.domain.

New Client files (ClientUpdater.java and ClientGui.java) are located in hottargui.client.

8.2.4 Comments to the progress of my hand-in

Because of periods of stress I ran out of time. I was not able to catch up finishing the architectural prototype :-(

Only code in skeleton form for the architectural prototype has been produced, so the class diagram drawn for the distributed client-server system has not been verified.

Other things that has not been clarified:

- Which information beyond game state information should be exchanged between client and server?
- How do we find the players?

9 Conclusion

During the course of writing this report and especially the code for it, we verified what we already knew from experience; it is very difficult to develop on a common base of software geographically dispersed. Modern communication forms and code repositories naturally greatly improve the ability of working geographically seperate, but it is still quite a lot more difficult than working physically together.

This fact is multiplied by the use of TDD, which is an XP inspired approach and it therefore relies heavily on quick-reaction and pair-programming, which has caused some problems. It was however very educational to use TDD to this degree, as it is, in its pure form, mostly left for academia.

With compositional design the opposite was true, however. The strength of the design principle could clearly be seen in how easily multiple strategies and patterns, designed and written separately, was combined with ease – a great improvement over polymorphic design.

Developing variants requires the basis code base to be stable, so the interfaces of the base do not change during development of the variants. One needs to be aware of the amount of interfaces and classes created by using the compositional design. The mass of classes and interfaces are quickly becoming hard to handle unless documented in a good fashion. It is useful to document the code changes after the end of each “refactor step” when using TDD. This can be done using simple UML-diagrams where only the most important details are included. The documentation will also provide as a very good communication tool when developing a project over geographical distances.

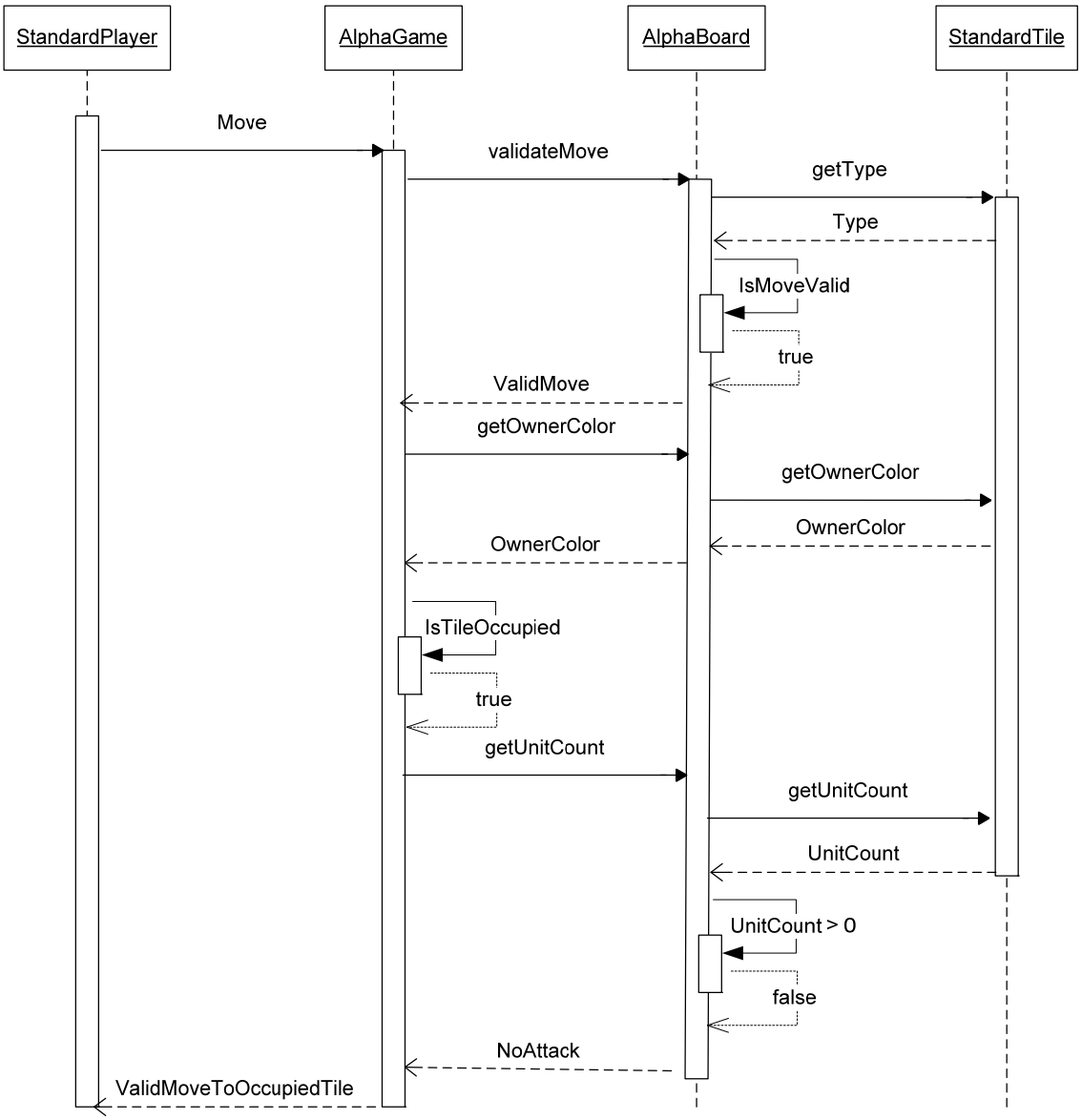
Because of all the test cases that have been written during TDD we felt very confident about implementing new strategies. For instance when implementing AlphaPutUnitsStrategy during development of BetaTargui is was great to see that all test cases for AlphaTargui succeeded.

The architectural prototypes also proved this fact, in how easy the code could be stripped down and a prototype written on top. Having the proof-of-concept, prototype, Hello-world, or whatever a back finding-mission in SW is usually called, clarified, formalized and documented as a technique is a strong tool for developers and combining them with quality attributes gives a higher degree of clarity into what it is that should be found out. In practise the architectural prototype was shown to be a strong way of showing possible solutions in a ”simple” and understandable way, and proved that prototypes can definitely be used for more than user interfaces.

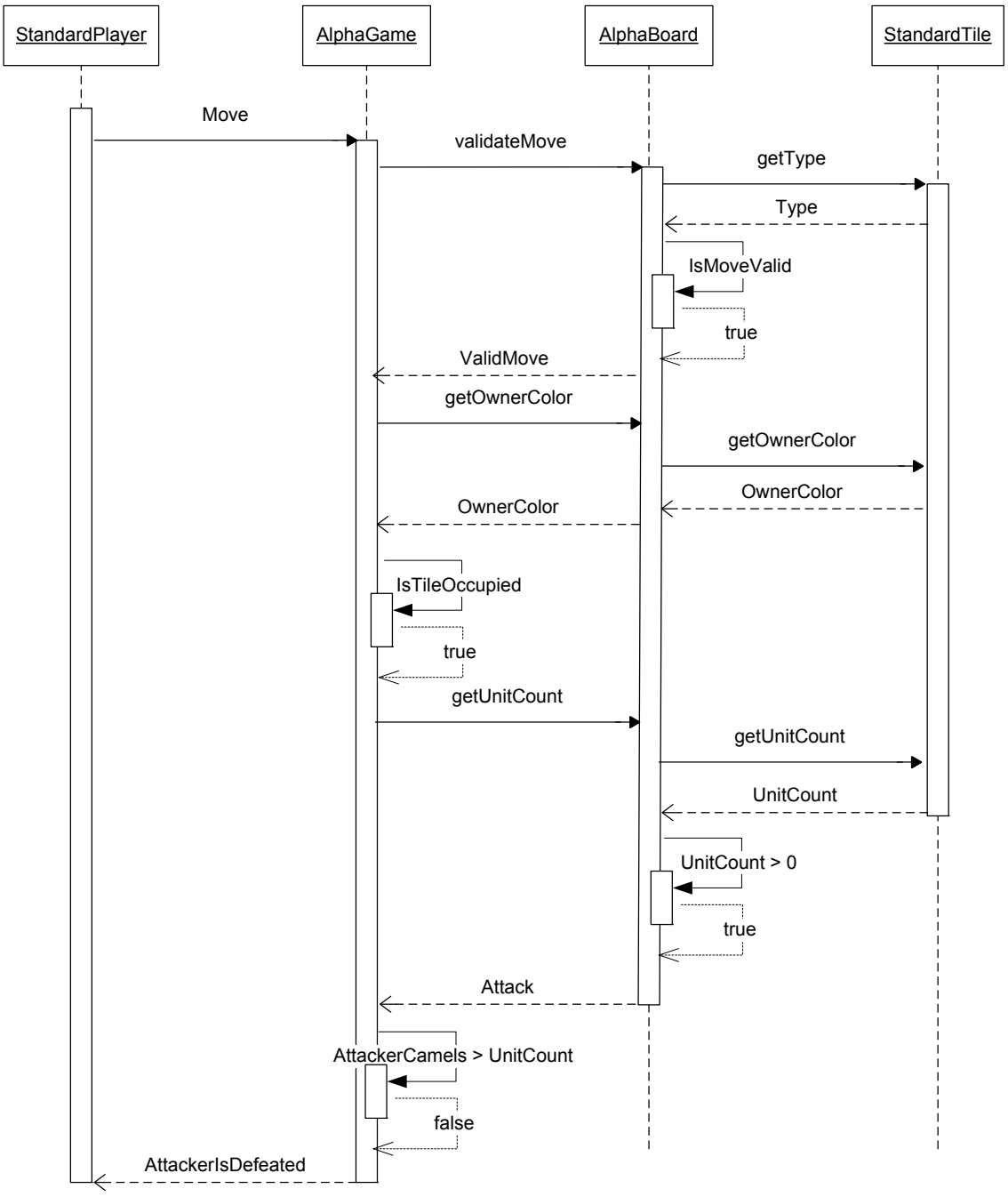
10 Appendix

10.1 Appendix 1: Sequence diagram for “Moves”

10.1.1 Valid move to occupied tile with no camels



10.1.2 Attacker has less camels than defender (Attacker is defeated)



10.2 Appendix 2: Software Quality Attributes for the implementation of HotTargui

10.2.1 Modifiability Scenario

HotTargui can be played by 2 to 4 players depending on the game variant. Thus we have found something that varies in our system. It shall be easy to modify the software to implement the different variants. This means that the modifiability quality attributes is very important for our system.

Portions of scenario	**Values**
Source	Developer.
Stimulus	Wish to make a new game variant
Artifact	Code
Environment	Design Time.
Response	The modification is made with no side effects.
Response measure	The time to make the modification should be less than 3 days.

10.2.2 Testability Scenario

It is mandatory that code is developed using test-driven development process. Thus testability quality attributes is also very important for our system.

Portions of scenario	**Values**
Source	Unit developer
Stimulus	Design (writing code)
Artifact	Piece of code (Component of the system)
Environment	At development time
Response	Unit can be controlled and its responses captured
Response measure	Green bar (or red bar)

10.2.3 Usability Scenario

Since we are in the gaming world usability is important. To become popular, a game should be easy to learn and easy to use. To support “use system efficiently”:

Portions of scenario	**Values**
Source	End user
Stimulus	Wish to learn to use the system
Artifact	The system (game)
Environment	Normal operation at runtime
Response	User gets instructions that he/she can read
Response measure	After 30 minutes the user is familiar with playing the game

10.2.4 Performance Scenario

Performance is often an important part of usability. The system must respond requests from user (mouse click or key press) within a reasonable time.

Portions of scenario	**Values**
Source	Users
Stimulus	Move, attack or buy units
Artifact	The system (game)
Environment	Normal operation at runtime
Response	Move, attack or buy units are processed by the system.
Response measure	Within 2 seconds

10.2.5 Availability Scenario

Notifying end user about faults is also a parameter to improve usability. In our case a restart of the system (game) would probably solve all faults. Thus the availability quality attributes are not very important for our system.

Portions of scenario	**Values**
Source	User input
Stimulus	A component fails to respond to an input
Artifact	The system
Environment	Normal operation
Response	Notify end user about the problem.
Response measure	Restart of system must only take 5 seconds

10.2.6 Security Scenario

Not important for our system and therefore there are no description of this scenario.