Individual Research Paper

ENGN2225 Systems Engineering Design

Green at Heart – System Function Definition

Ryan Bradley
u5351414.email@anu.edu.au
W10A

Abstract

System Functions utiliises the method of functional analysis to break up a system or technology into a number of components to analyse how that technology is used. System Functions also requires a concept generation be performed to scope potential solutions to the current problem.

In this paper, functional flow-block diagrams are used to perform a functional analysis on the use of a traditional garden hose. This is done in order to examine the problem of a wheelchair bound woman who is unable to water the garden as she unable to turn on and hold a hose. Concept generation is used to identify different solutions which will allow the woman to water the garden by herself. The concepts are compared against the client's design requirements and narrowed down to the top three concepts. Lastly, a functional analysis is performed on the top three concepts to identify how they will be used.

Project Background

My group's topic, Green at Heart, involves participants in a project called MULCH which gives people with both mental and physical disabilities the opportunity to contribute to society by helping to grow and maintain a garden. One of the participants in the program is wheelchair bound and is unable to hold a garden hose due to low motor control in her hands. Designing a solution which will allow her to water the garden will give her a sense of pride and independence as it will decrease her reliability on her carer. Our group proposes two separate solutions to give her this independence. Firstly, to design a solution which will allow the client to turn on the hose herself, and secondly, to design a concept which will allow her to control and aim the hose herself.

Theory Review

A System Function Definition requires a functional analysis and concept generation be performed to achieve a number of outcomes in a particular project. Functional analysis requires breaking up an idea or technology into steps to see how the technology functions under normal use (NASA n.d.). Concept generation uses the method of brain storming to come up with potential solutions to a problem. In this paper, a functional analysis and a concept generation will be undertaken to address the problem of the wheelchair bound woman with low motor control in her hands being unable to turn on, hold and use a garden hose.

The functional analysis performed will identify the steps required for using a traditional garden hose. The steps will be identified using a Functional Flow-Block Diagram (FFBD) (Blanchard, B.S. & Fabrycky, W.J. 2011). FFBDs allow a person to physically visualise the functional steps of a process and are a very important and popular tool in systems engineering. Creating an FFBD involves establishing several blocks connected by arrows which flow from left to right (McInnes, A & Eames, B & Grover, R 2011) (See Figure 1). Accompanying these arrows may be one of two functions, the '&' function or 'OR' function (or neither). The arrows associated with the '&' function require that all blocks must be completed. Whereas the arrows associated with the OR function require that only one of the interconnecting blocks needs to be addressed. Within each block is a function that is required for the operation of the system. For this project, each block will contain a function which is required for the use of a traditional garden hose.

After completeing the functional analysis, a concept generation will be performed by brainstorming different ideas. The ideas generated will be tested against the project's design requirements which will narrow down the concepts to the three best solutions (Brown, C 2014). Another functional anaylsis will then be performed on these three best concepts to see how each concept will be used.

Application

Part of the FFBD for using a traditional garden hose is shown in Figure 1 below (Note: the rest of the FFBD can be found in Figure 3 in the Appendix). The FFBD below shows there are five main steps when wanting to use a garden hose. At the present time, all steps of all levels of the FFBD are completed by the carer of the client. The carer must even water the garden for the client. Therefore it is evident that a solution is needed as to allow the client to do at least some of the work.

The second level functional flow shows there are a number of intermediate functions required before actually turning on the hose. If the method of generating an FFBD was not used, these intermediate steps in the second level may not be considered in our solution. It may also be the case that one of these intermediate steps is essential for our solution and if it is not identified until very late in the project, it might be too late to change it. Therefore it is imperative these steps are considered now so we can include them in any solution if necessary.

Figure 1 also shows the maintenance flow-block diagram for the intermediate steps between blocks 2 and 3. The maintenance flow-block diagram shows two potential directions you can take. Once direction assumes there are no faults in the performance of the system. The other direction shows the potential faults that may hinder the performance of the system. Two faults were identified which could prevent the system from functioning at its desired performance.

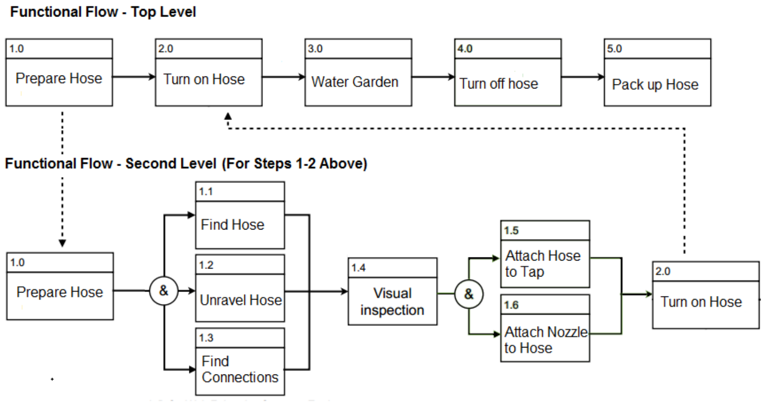


Figure 1: FFBD for using a garden hose (See Figure 3 in Appendix for the full and enlarged FFBD)

From analysing the above FFBD, the steps which need to be addressed are blocks two to four. The solution only needs address turning the hose on and off and the actual watering of the garden. It is assumed client does not have the capacity to complete steps one and five. Therefore it will be assumed that the client's carer will complete these two steps. The carer will also have to complete block two if the hose is not functioning properly due to the reasons given in the maintenance flow-block diagram.

Now that the functional analysis has been completed, a concept generation must be performed to identify various solutions to blocks two to four above. The group's solution wants to allow the client to both turn on the hose and control it. The table below shows the results from the brainstorming of ideas to control the hose and ideas to turn on the hose.

Table 1 (See Table 1 in Appendix for an enlarged version of the table):

Turn On Hose	Controlling the Hose
Lever (Sticks vertically out of wheelchair arm. Push forward to turn on. Pull back to turn off)	Swivel (Mount to arm of chair. Client holds swivel and rotates it up to 180 degrees about the vertical axis)
Button (Sits on wheelchair arm. Press to turn on water. Press again to turn water off.)	Shaft (Sticks out of wheelchair. Client grips shaft and maneuvers it and aims toward garden)
Handle (Similar to existing hose connection designs. Squeeze and hold handle for water to come out)	Rigid Attachment (Attaches to arm of chair and does not allow the hose to move, it only can spray forwards)
Touch Screen (Similar to iPad. Press on touch screen icon to start and stop water flow)	Forearm Attachment (Attaches to forearm. Just need to move arm to aim hose)
Foot Pedal (press pedal with foot to start and stop water flow)	Ball and Socket Joint (Mounts to wheelchair arm. Place hose into a connection then grasp hose and rotate and move it about the joint's range of motion.
Slide Lever/Handle (Sits on wheelchair arm. Slide handle forward to turn on hose. Spring slides handle back into original position. Slide handle forward again to turn off.	Flexible Tripod (Similar to ball and socket joint. Mounts to wheelchair arm or forearm. Attach hose to connection then grasp hose and rotate and move it about the tripod's range of motion. Or move arm to aim hose at garden)
Pressure Chamber (Pump water then press lever to spray. Similar to a weed killer)	

The five top ranked design requirements, which were found using a pairwise analysis and house of quality, were (From highest to lowest rank): fun, mountable, simple, lightweight and portable. Comparing these requirements to the concepts in Table 1 will enable the concepts to be narrowed down to the best three.

For turning on the hose, the touch screen, foot pedal, handle and pressure chamber solutions are ruled out because they will be difficult for the client to use. This is because the client is unable to maneuver her fingers and it is assumed she does not have much strength in her legs, therefore pressing a small icon, squeezing a handle and pressing a foot pedal may prove too difficult for the client. This would mean the carer would have to do most of the work, which would not provide much enjoyment for the client.

For using the hose, the swivel, the shaft and rigid attachment solutions are ruled out because they, once again, will be too hard to use. Since the client cannot grip a hose, she most likely will not be able to grip and move the swivel or the shaft. The rigid attachment is not appropriate because it does not allow any interactivity, meaning it will not be fun to use.

Adhering to the design requirements, the three best solutions for turning on the hose are the lever, the button and the sliding lever. The three best concepts for controlling the water are the forearm attachment, the ball and socket joint, and the flexible tripod. These solutions will provide enjoyment and fun for the client, as well as being mountable, simple, lightweight and portable.

Applying the functional analysis again, the steps required for using these solutions are demonstrated in the FFBD, Figure 2, below (See Figure 4 in Appendix for enlarged FFBD.)

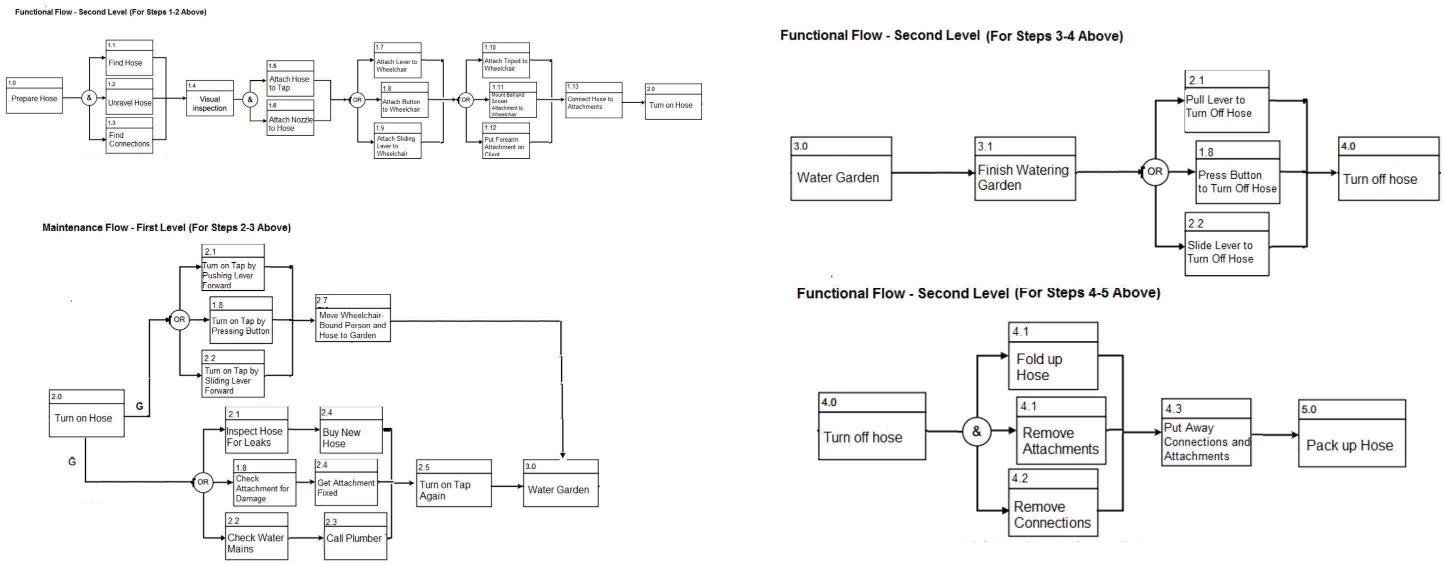


Figure 2: FFBD for top three generated concepts (See Figure 4 in the Appendix for full sized FFBD)

Discussion

It is not entirely certain how each concept is going to be designed yet. Therefore, it is hard to determine how each concept will be used. This made it difficult to model and analyse the concepts in the FFBD as the exact details of use have yet to be established. Once the concepts have been more properly defined it will be possible to create a more detailed and refined FFBD. At the present time, the FFBD suggests that all the concepts require similar maintenance, time and difficulty by both the client and the carer to set up, turn on and water the garden.

Now that concepts have been modelled, the group can now begin to assess each design more thoroughly to determine which concept will be the best solution for the client. The FFBD in Figure 2 suggests that the flexible tripod may be the best solution for controlling the water while the sliding lever or the button might be the best option for turning on the hose. The tripod might be the best concept because it would require less parts and connections, making it simpler for the carer to attach to the client. Also, since it is flexible, it has the advantage of being able to be attached anywhere, such as the clients arm or the wheelchair arm. The other attachments do not allow for this. As seen in the second level functional flow between steps three and four, the lever must be pulled back to turn off the hose. This is not ideal as pulling the lever requires that you must be able to grasp it. Since the client is unable to hold a hose, it is unlikely she will be able to grip a lever.

Conclusion

From the use of the functional analysis technique, the steps required to use a garden hose were identified. From there, a concept generation was performed which identified a number of potential solutions. These concepts were for turning on the hose and for using the hose. Both solutions were narrowed down to the best three by comparing them to the client's design requirements. The three best solutions for turning on the hose were the lever, the sliding lever and the button. While the three best for using the hose were the flexible tripod, the forearm attachment and the ball and socket mount. These concepts were modelled by an FFBD to see how each would be used.

References

Blanchard, B.S. & Fabrycky, W.J. 2011, *Systems Engineering and Analysis*, Fifth ed. Pearson, New Jersey, viewed 21/03/2014, <http://eng.anu.edu.au/courses/ENGN2225/course-files/further_resources/wk06-Blanchard_FFBDs.pdf>

McInnes, A & Eames, B & Grover, R 2011, *Formalizing Functional Flow Block Diagrams Using Process Algebra and Metamodels*, viewed 21/03/2014, <http://ieeexplore.ieee.org.virtual.anu.edu.au/stamp/stamp.jsp?tp=&arnumber=5484567>

NASA, n.d. *Functional Analysis Module*, USA, Viewed 21/03/2014, <http://kscsma.ksc.nasa.gov/Reliability/Documents/Functional_Analysis_Module_V10.pdf>

Brown, C 2014, *Functional Flow Block Diagrams*, Australian National University, Australia, viewed 21/03/2014, <http://www.youtube.com/watch?v=Ii1MI68MKDs&feature=share&list=PL2hygCecjFiXEDTXwBOgWlAFVZL06gnSA>

Brown, C 2014, *Concept Generation*, Australian National University, Australia, viewed 21/03/2014, <http://www.youtube.com/watch?v=MW2HQ8mgaDo&feature=share&list=PL2hygCecjFiXEDTXwBOgWlAFVZL06gnSA&index=7>

Peer Review Critique

Both critiques were very positive, constructive and helpful. The comments allowed me to develop a much sounder piece of work than my draft.

It was mentioned in the first critique that I must include a real world example of when a functional analysis had been performed. I did not agree with this because it says in the template, “You might find it more logical to have a Project Background section (eg. what your project is) and a Theory Review section (eg. what theory are you using).” So unless I misinterpreted the template, I thought it was not necessary to include the literature review if I instead used the Project Background and Theory Review sections.

The two reviewers said completely different comments about the text on page four. The first critique deemed the explanation on how I used the design requirements to choose the best three concepts redundant and unnecessary. He believed that the explanation was not closely related to the main theory series of this course. He also thought that I should explain how my group ranked our design requirements. I agreed with this so I very briefly mentioned the methods our group used to establish the ranking. The second critique believes the discussion on page five was excellent and my referrals back to the design requirements were a good idea. I agreed with the second critique which is why I did not remove the discussion.

The first paper believed I should provide an explanation of the ‘&’ and ‘or’ functions in the FFBD discussion. I thought this was a good idea so I added a brief explanation on the use of the two functions.

The first critique was helpful for the development of my abstract. I originally had paragraph with sources in the abstract which he believed would be more appropriate in the Theory Review section. I agreed with this so I moved it.

Appendix

Figure 3 – FFBD for using a normal garden hose:

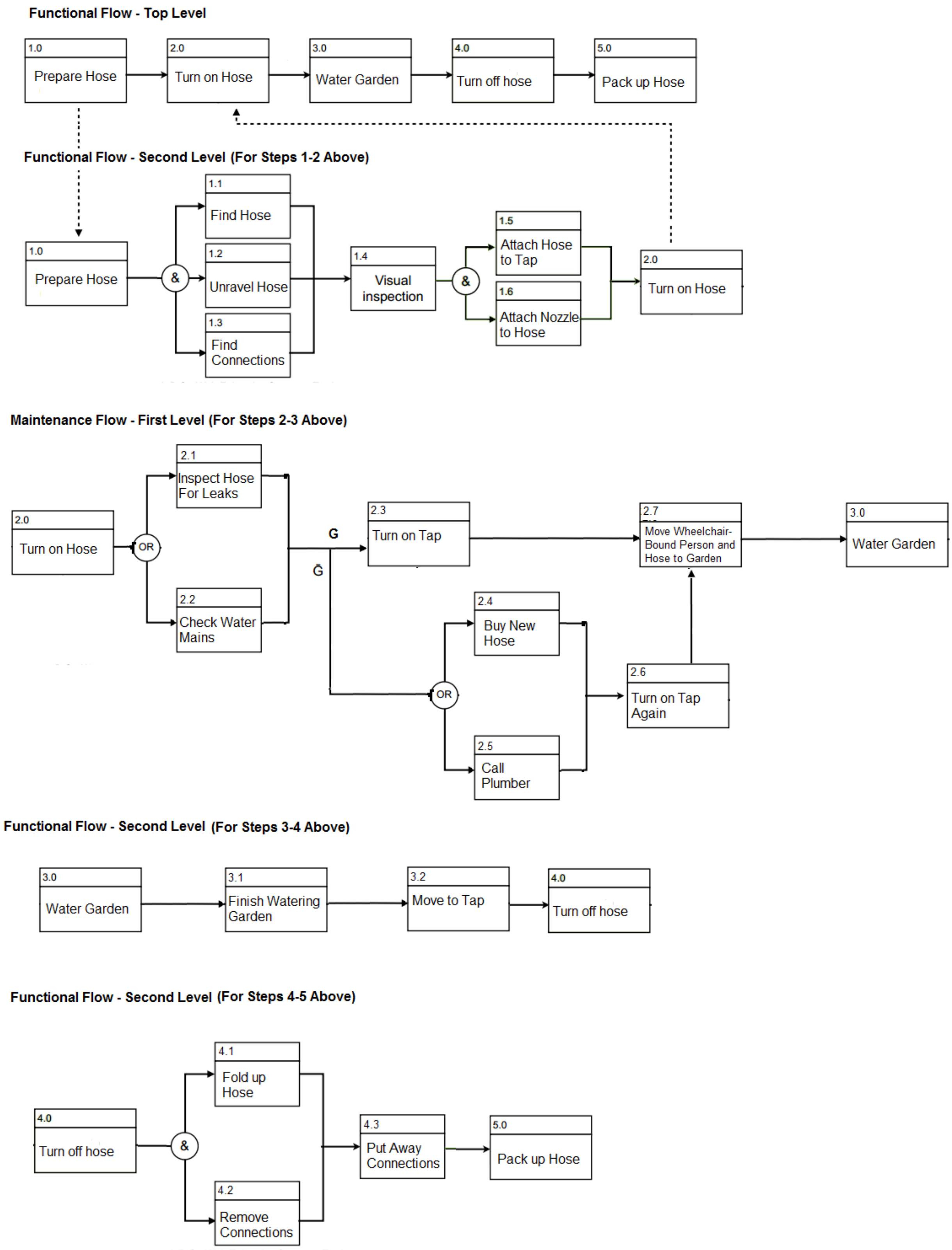


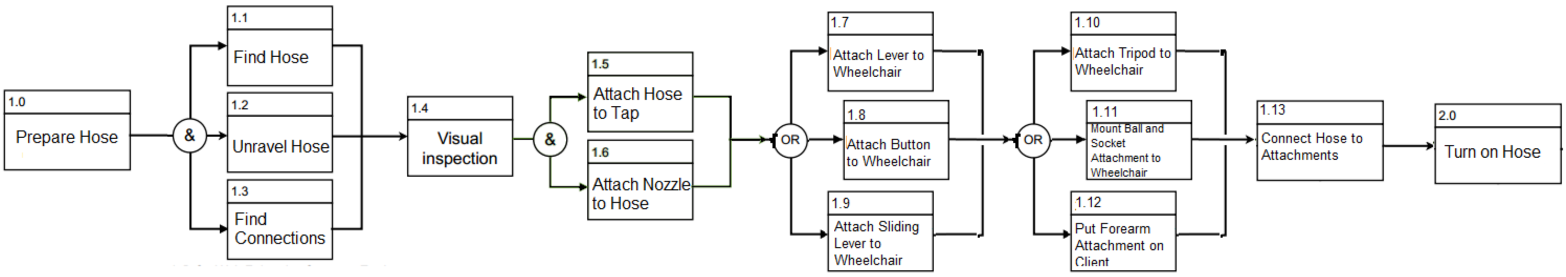
Figure 3: FFBD for using a garden hose

Table 1 – Concept generation brainstorm:

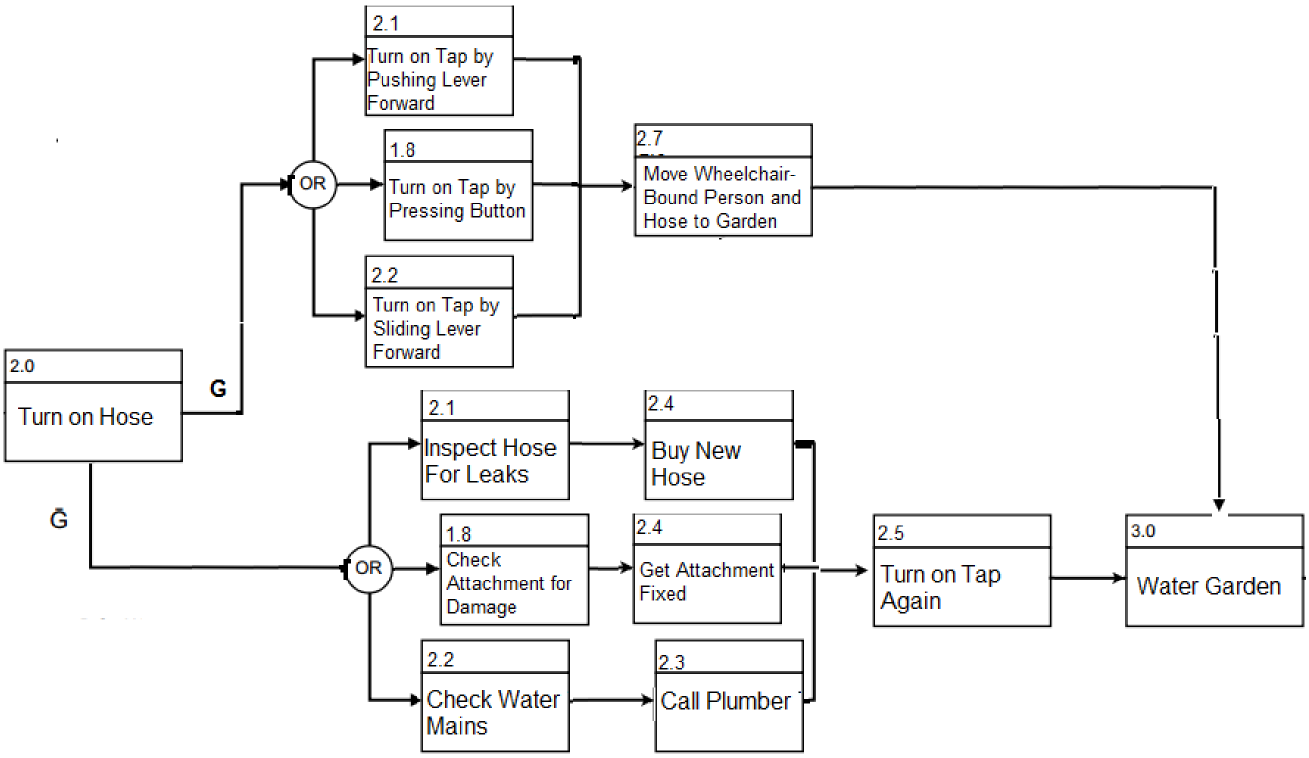
Turn On Hose	Controlling the Hose
Lever (Sticks vertically out of wheelchair arm. Push forward to turn on. Pull back to turn off)	Swivel (Mount to arm of chair. Client holds swivel and rotates it up to 180 degrees about the vertical axis)
Button (Sits on wheelchair arm. Press to turn on water. Press again to turn water off.)	Shaft (Sticks out of wheelchair. Client grips shaft and maneuvers it and aims toward garden)
Handle (Similar to existing hose connection designs. Squeeze and hold handle for water to come out)	Rigid Attachment (Attaches to arm of chair and does not allow the hose to move, it only can spray forwards)
Touch Screen (Similar to iPad. Press on touch screen icon to start and stop water flow)	Forearm Attachment (Attaches to forearm. Just need to move arm to aim hose)
Foot Pedal (press pedal with foot to start and stop water flow)	Ball and Socket Joint (Mounts to wheelchair arm. Place hose into a connection then grasp hose and rotate and move it about the joint's range of motion.
Slide Lever/Handle (Sits on wheelchair arm. Slide handle forward to turn on hose. Spring slides handle back into original position. Slide handle forward again to turn off.	Flexible Tripod (Similar to ball and socket joint. Mounts to wheelchair arm or forearm. Attach hose to connection then grasp hose and rotate and move it about the tripod's range of motion. Or move arm to aim hose at garden)
Pressure Chamber (Pump water then press lever to spray. Similar to a weed killer)	

Figure 4 – FFBD of the top three generated concepts:

Functional Flow - Second Level (For Steps 1-2 Above)

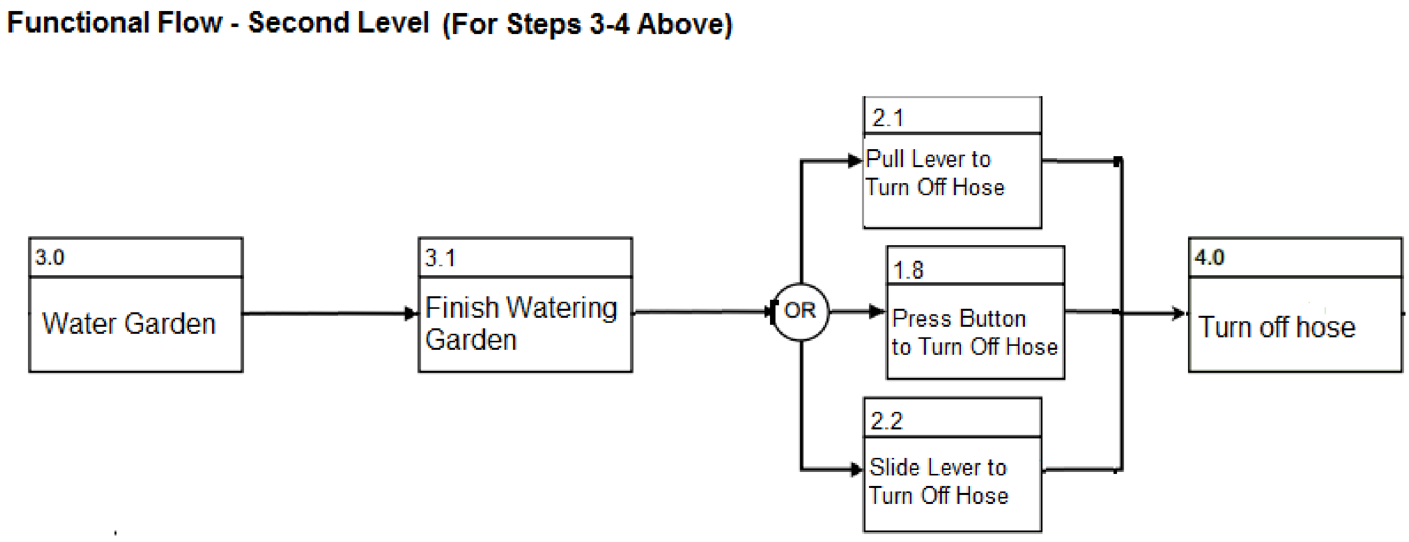


Maintenance Flow - First Level (For Steps 2-3 Above)



(*See next page for the rest of the FFBD)

Figure 4 (Cont.)



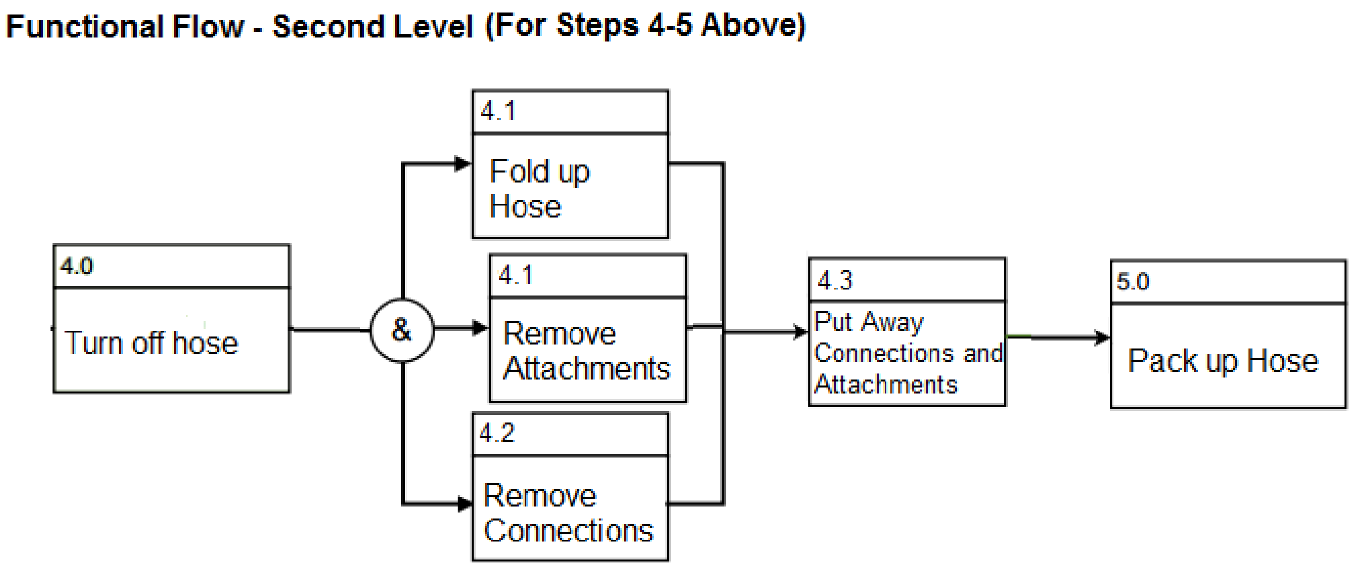


Figure 4: FFBD for top three generated concepts