

Designing preterm muscle tone and arm movement simulation

Citation for published version (APA):

Peters, P. J. F., Delbressine, F. L. M., & Feijs, L. M. G. (2013). Designing preterm muscle tone and arm movement simulation. In E. Purshotaman (Ed.), *Proceedings of 2013 International Conference on Biological, Medical and Chemical Engineering, December 1-2, 2013, Hong Kong* (pp. 147-150). DESTech publications.

Document status and date:

Published: 01/01/2013

Document Version:

Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

Designing Preterm Muscle Tone and Arm Movement Simulation

P. PETERS^{1,a,*}, F. DELBRESSINE^{1,b} and L. FEIJS^{1,c}

¹Eindhoven University of Technology, Department of Industrial Design,
P.O. Box 513, 5600MB Eindhoven, The Netherlands

^ap.j.f.peters@tue.nl, ^bf.l.m.delbressine@tue.nl, ^cl.m.g.feijs@tue.nl

*Corresponding author

Keywords: Simulation, Design, Safety.

Abstract. Of all babies born, only a small percentage is premature but this small percentage accounts for a large portion of infant deaths [3]. Training for health risk assessment is one of the factors that might help in lowering the mortality of premature neonates. Designing tools that support this type of training improves the safety of the premature neonates at risk. The topic of this paper is the design and implementation of arm movement and muscle tone simulation in a premature neonate simulator that can be used for team training of gynecology emergency response teams.

Introduction

The initial assessment of a newborn infant includes global examination of the central nervous system. This can easily be studied by inspection of the infant with respect to the presence/absence of spontaneous movements and the posture of the extremities. If a neonate is healthy it shows signs of activity for instance by moving its arms and legs. If the neonate is inactive it usually is a sign something is wrong. A physician will then examine the newborn more in detail. One of the elements of examination is muscle tone, a continuous, passive, partial contraction of the muscles. This paper covers the design of the activity component in the premature baby manikin, allowing the simulation of movement and muscle tone.

Design

To generate ideas for the mechanical solutions required we looked at:

Medical Aspects

Evaluation of a newborn infant starts with inspection of movement of the limbs and posture of the limbs. Subsequently muscle tone is assessed. To measure muscle tone, the physician applies a certain force to joints in the legs or arms of the neonate by trying to move them in specific positions (flexion and extension of the limbs) [1] and checking the amplitude of movement. While applying this procedure the physician can appreciate a certain amount of resistance. If the baby has muscle tone, some resistance can be felt; if muscle tone is absent, no resistance is felt.

Physiological Aspects

Construction of the arm and shoulder joints and how they move by muscle contractions.

This results in a first list of demands and wishes. The manikin should be able to simulate the presence and absence of some of the arm movement as seen in a neonate, e.g. moving arms up and down. Also the muscle tone related resistance -or the absence thereof- when moving the arms of the child has to be simulated. A major problem creating the demands and wishes for muscle tone is the absence of quantitative data which can be explained by the qualitative way muscle tone and movement are evaluated.

Technical Challenges. The major challenge in designing arm movement and muscle tone is of mechanical nature. Arm movements can be short and fast and although they are short in duration, the rotation involved can be large (up-to 90 degrees). For our simulation purposes a focus on specific, limited movement and resistance against enforced movement will do, since these are the first movement factors judged by physicians. Following the elementary principles of Mechanical Design [5] we try to create designs that are explicitly simple, keep the functions of a design independent from one another, use exact kinematic constraints when designing structures and mechanisms and manage friction in mechanisms. We realized a mechanical design that is a simplified model of the neonate's arm that allows rotation around one axis in the shoulder joint.

Physics. The forces, torques and especially the power needed to generate arm movements need to be determined to estimate the needed power and energy as well as to design the mechanics. The power and energy needed are of importance because the target is a stand-alone baby manikin. The available space inside the manikin is limited and therefore batteries need to be small, so only a small amount of power/energy is available. A first order power estimation assuming an arm weight of 25 [gr], a movement angle of 45° and a movement time of 1 [s] leads to a power usage of approximately 10 [mW].

Muscle Tone Design Explorations. Absence of muscle tone does not require actuators (see Fig. 1a). Muscle tone also does not need actuators, a set of loaded springs can provide this type of inherent feedback (see Fig. 1b). Changing from absence of muscle tone to presence of muscle tone needs a change of configuration and thus an actuator is needed.

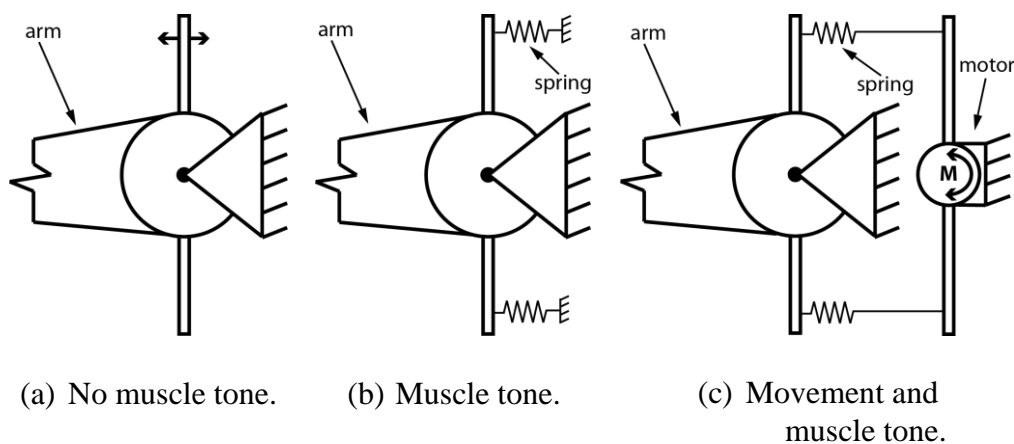


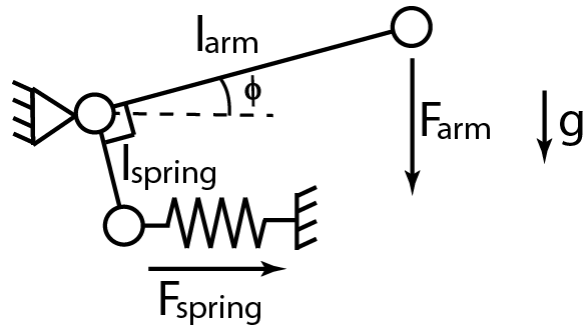
Figure 1. Models.

We explored several possible mechanisms for generating muscle tone, starting from single spring passive systems, multi spring passive systems, variable spring systems, actuated systems with and without feedback up to systems that combine actuation and springs.

Arm Movement Design Explorations. The real biological shoulder and elbow mechanics are more complex. For the simulation we restrict movement possibilities and implement shoulder rotation in a single plane and no elbow rotation. Using simplified models like shown in Fig. 1c and Fig. 2b and applying Physics we can estimate the forces required for movement which allows defining some actuator requirements. Several mechanical explorations ranging from using toroid springs and motors, solenoids, a stepper motor and a servo motor were tested. More solutions were considered, like using Nitinol wires, artificial muscles, voice coil actuators and pneumatic actuators, but these were not considered viable, mainly because of force or volume constraints.



(a) 3D printed manikin.



(b) Simplified arm model.

Figure 2. 3D printed manikin and force model.

Selection

Selection of the actuators is done based on the specifications resulting from calculations and experiences gained when building the explorations. Table 1 shows a summary of pros and cons that resulted from the movement experiments. As a general rule, actuators that deliver more force are bigger. This conflicts with the limited space available. Compared to the other options, the servo motor is the best option because of its high torque/size ratio, so a small servo motor is the preferred actuator based on the experiments and specifications. The noise generated by the servo can be reduced by damping. Wrapping the servo up in materials reduces sound radiation via air and using rubber reduces mechanical sound conduction between servo and chassis [4]. In all moving parts of the mechanical design friction plays an important role. In the case of the arm-joint, minimal friction is aimed for, thus ball bearings were used.

Table 1. Movement experiments test results.

Method	Pros	Cons
Solenoids	Silent	No proportional control Large size Continuously powered
Stepper motor	Continuous control Powered when loaded	Low torque/size ratio Noise
Servo motor	Continuous control High torque/size ratio Powered when loaded	Noise

Prototyping

To be able to do the experiments a real size, 3d printed mechanical platform was created that allowed to create several different mechanical implementations of arm movement and muscle tone.

Implementation

Fig. 3a shows the construction that was chosen for the final prototype. A servo placed on a movable sliding platform controls the rotation of the arms axle through 2 springs and 2 short pieces of Polyamide wire. The sliding platform allows the servo to be in various positions of which 2 are important: pulled back and pushed forward, dependent on the activation of a solenoid. This allows for simulating arm movement (sliding platform pulled back, servo rotating), muscle tone (sliding platform pulled back, servo not rotating), and no muscle tone (sliding platform pushed forward, servo not rotating). The Polyamide wire takes care that the relatively rigid springs do *not* cause a torque -and thus muscle tone- in the arms axle when the platform is pushed forward. The servo allows for the subtle arm movements as well as for bigger movements. Interfacing the servo motor to e.g. a

micro-controller is done using standard pulse width modulation [2] that directly controls the rotation angle of the servo.

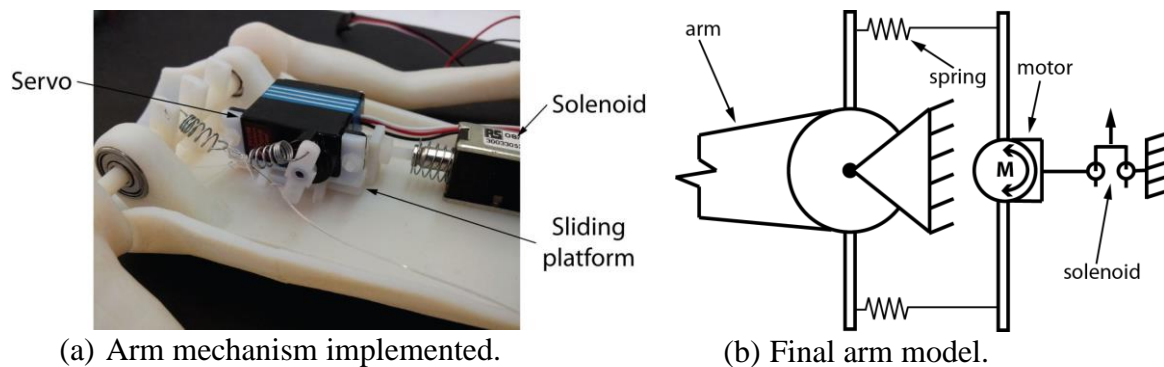


Figure 3. 3D printed mechanism and model.

Conclusions

Making the right choice for the actuators, sensors and mechanics that allow the movements required is not a straightforward task. The mechanical design depends on the actuators chosen, the actuators chosen depend on the torques needed and the torques needed depend on the mechanism designed. Besides thorough investigation of the requirements that can be theoretically deduced, a good amount of iterative design is therefore needed to accomplish that everything fits in the limited space and performs as required. The specifications of the currently chosen components are better than required, allowing for bigger angular acceleration. This e.g. also allows simulating the Moro reflex which requires a very fast arm movement ($\Delta t \approx 0.25$ [s]).

Acknowledgements

We would like to thank Prof. Dr. Sidarto Bambang-Oetomo, pediatrician-neonatologist at the Máxima Medical Center in Veldhoven, The Netherlands and part time professor at Industrial Design, for his support in the medical matters in this paper.

References

- [1] C. Amiel-Tison. Neurological evaluation of the maturity of newborn infants. *Archives of Disease in Childhood*, 43(227):89-93, 1968.
- [2] M. Barr. Pulse Width Modulation. *Embedded Systems Programming*, September 2001:103-104, 2001.
- [3] A. D. Mohangoo, S. E. Buitendijk, C. W. Hukkelhoven, A. C. Ravelli, G. C. Rijninks-van Driel, P. Tamminga, and J. G. Nijhuis. Higher perinatal mortality in The Netherlands than in other European countries: the Peristat-II study. *Nederlands tijdschrift voor geneeskunde*, 152(50):2718-27, 2008. English Abstract.
- [4] N.B. Roozen. *Quiet by Design: Numerical Acousto-elastic Analysis of Aircraft Structures*. Technische Universiteit Eindhoven, 1992.
- [5] J.G. Skakoon. *Detailed Mechanical Design : A Practical Guide*. ASME Press, New York, 2000.