



Figure-Eight Drive Handcycle Drivetrain

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Figure-Eight Drive

- A low cost two speed handcycle drivetrain designed for the developing world.
- Allows for two forwards gears that can be switched between simply by changing the direction of pedaling.
- I came up with the design during the course SP.784: Wheelchair Design for Developing Countries (WDDC) in Spring 2007.
- I implemented it last summer in Kenya on a MIT Public Service Center Fellowship



Wheelchairs in the Developing World

- Often donated from developed countries.
 - Difficult/impossible to repair locally
- Not suited to the demands of developing countries:
 - Travel over rough terrain
 - Travel over long distances, sometimes up to 5 km/day.

An Alternative: Handcycles



Photo courtesy of Amos Winter

- Can be manufactured and repaired locally out of readily available bicycle components.
- Well suited to the demands of developing countries:
 - Long wheelbase makes them stable over rough terrain
 - Biomechanically more efficient than wheelchairs, making long distance travel bearable

Current Handcycle Systems



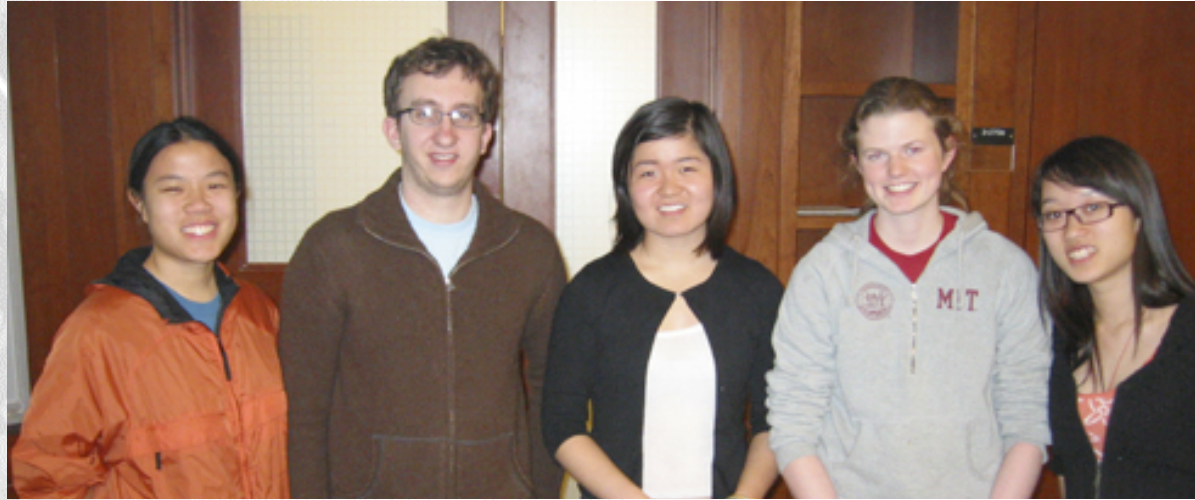
- Most are single speed bicycle transmissions
 - Starting motion and traveling up hills requires high torque inputs: is very difficult for most users.
 - Applying high forces to the pedals applies a torque about the steering axis, making it almost impossible to drive straight up hills



Current Handcycle Systems

- Multi-gear derailleur systems exist but are unpopular for several reasons:
 - Changing gears is difficult because users must remove one hand from the pedals to manipulate the shifters
 - The derailleurs are of poor quality, often breaking within several weeks, stranding users in a single gear.
 - The systems are difficult to manufacture, making them up to 50% more expensive than single speed models.

WDDC Biomech 2007



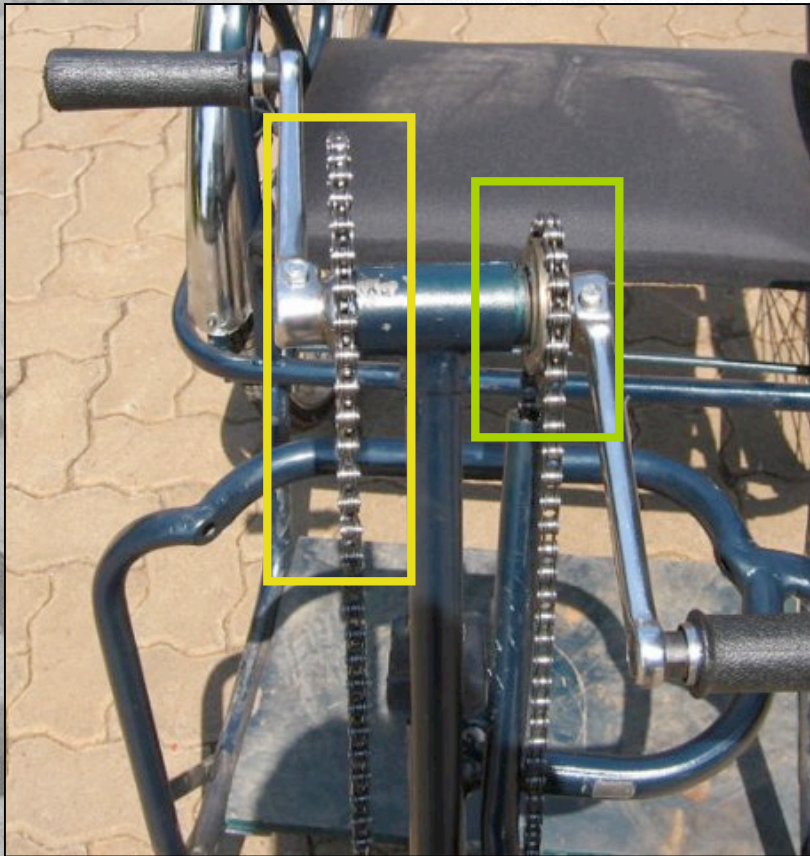
- Elizabeth Au, Mario Bollini, Xin He, Lindsay Todman, and Katherine Wong with Amos Winter and Gwyndaf Jones
- Looked into alternative tricycle propulsion techniques before decidign to try to optimize the tricycle gear ratios and shifting systems.
- Mario spent the summer at APDK in Kenya.
- Lindsay spent the summer at DAGE in Tanzania

Figure-Eight Drive



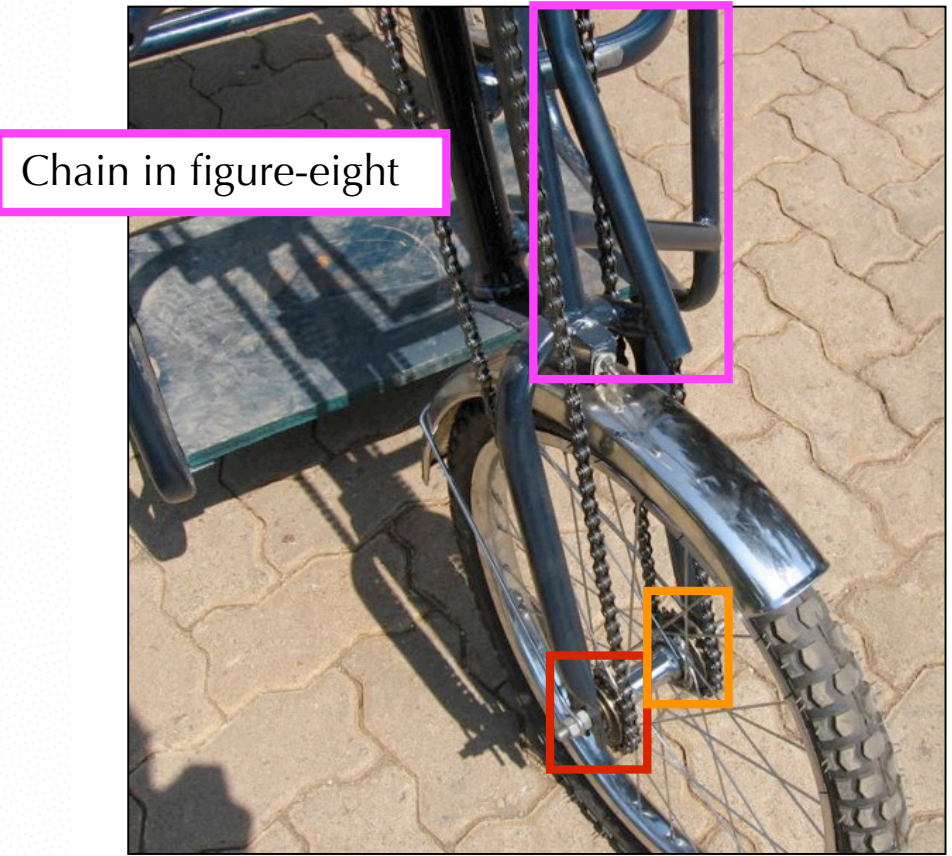
- Offers users two forwards-motion gears, one high and one low
- The gears are shifted by changing the direction of pedaling.
 - Pedaling forwards provides a 1:2.25 gear ratio
 - Pedaling backwards provides a 1:1 gear ratio
 - Both pedaling directions produce **forwards** motion

Figure-Eight Drive



Standard
bicycle crank

Standard freewheel,
oriented backwards



Chain in figure-eight

Standard freewheel,
oriented normally

Standard freewheel,
oriented normally



Video Demonstration

- Shipping costs from Kenya ~ \$1000
- (please pardon the transition necessitated by QuickTime's video codec deficiencies)

Backwards Compatibility



Handcycle can only go **FORWARDS**



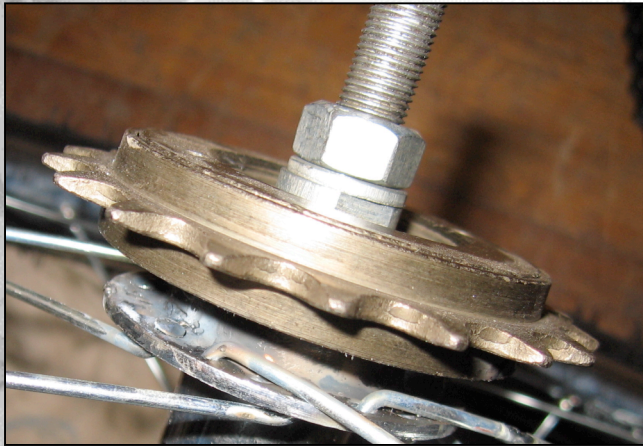
Handcycle can only go **BACKWARDS**

Design Implementation



- Was granted a fellowship by the MIT Public Service Center to spend the summer of 2007 in Nairobi, Kenya.
- Worked with the Association of the Physically Disabled of Kenya (APDK), an NGO that manufactures handcycles and wheelchairs across Kenya.

System Manufacturing



- All manufacturing can be accomplished using bicycle parts that APDK already uses for other products with methods common in developing countries.
- Requires approximately 1 hour more labor than APDK's single-speed handcycles
- Uses approximately \$3 more parts/material than APDK's single-speeds
 - APDK Single-speed retail price: \$200
 - APDK Multi-speed derailleur retail price: \$300

Developed 5 Prototypes



WDDC Demo

Generation A

Generation B

Generation C



User Testing



- The drivetrain was tested informally by dozens of local handcycle users in the APDK compound.
- Formal survey comparison testing was conducted with 8 handcycle users and 4 manufacturing technicians.
- While I was at APDK, one prototype was permanently given to a user for long term testing. Since then, three others have been distributed for testing.
- All survey results have come back extremely positive.

Long Term Testing



Durability Testing



- I spent much of the latter part of the fellowship trying to break the prototypes under harsh riding conditions.
- I also created a testing stand that allowed me to artificially manipulate the drivetrain.
 - Manipulated the low gear an equivalent of over 100 km
 - Alleviated concerns about chain wear in the figure-eight



Results

- The Figure-Eight Drive was presented by APDK to the Pan-African Wheelchair Congress in September, 2007.
 - Over 100 copies of the manufacturing plans were distributed to interested African wheelchair and handcycle manufacturers
- Prototypes have also been constructed by local manufacturers in Tanzania and the Philippines.
- APDK is awaiting the final results (the feedback currently positive) of the long term testing before integrating the Figure-Eight Drive into its full product line.



Impact

- The Figure-Eight Drive is superior to current single and multiple speed handcycle systems.
 - It can easily traverse terrain impossible to access with single-gear drivetrains.
 - It is easier to use, cheaper to manufacture, and significantly more robust than derailleur systems.
 - It is affordable and can be manufactured and repaired worldwide.



Impact

- The fellowship was an invaluable experience
 - Grounded theoretical education in a practical project
 - Used engineering to help people in the real world.
 - Allowed me to interact with a different and exciting culture.

The Big Dome



People



Culture



Safari



Acknowledgements



MIT Mobility Laboratory

SP.784: Wheelchair Design for Developing Countries



MIT Public Service Center



Association for the Physically Disabled of Kenya



For More Information

Detailed information about the Figure-Eight Drive, including pictures, videos, design notes and complete manufacturing instructions, can be found at:

<http://web.mit.edu/mbollini/www/tricycle/>