



AFRL-AFOSR-JP-TR-2022-0044

Discovering patterns in human-robot interaction: New tools for complex adaptive social systems - UCSD part

Chiba, Andrea
UNIVERSITY OF CALIFORNIA, SAN DIEGO
9500 GILMAN DR
LA JOLLA, CA, 92093
USA

06/01/2022
Final Technical Report

DISTRIBUTION A: Distribution approved for public release.

Air Force Research Laboratory
Air Force Office of Scientific Research
Asian Office of Aerospace Research and Development
Unit 45002, APO AP 96338-5002

REPORT DOCUMENTATION PAGE

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.

1. REPORT DATE 20220601	2. REPORT TYPE Final	3. DATES COVERED	
		START DATE 20170124	END DATE 20200123
4. TITLE AND SUBTITLE Discovering patterns in human-robot interaction: New tools for complex adaptive social systems - UCSD part			
5a. CONTRACT NUMBER FA2386-17-1-4006	5b. GRANT NUMBER	5c. PROGRAM ELEMENT NUMBER 61102F	
5d. PROJECT NUMBER	5e. TASK NUMBER	5f. WORK UNIT NUMBER	
6. AUTHOR(S) Andrea Chiba			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) UNIVERSITY OF CALIFORNIA, SAN DIEGO 9500 GILMAN DR LA JOLLA, CA 92093 USA			8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) AOARD UNIT 45002 APO AP 96338-5002		10. SPONSOR/MONITOR'S ACRONYM(S) AFRL/AFOSR IOA	11. SPONSOR/MONITOR'S REPORT NUMBER(S) AFRL-AFOSR-JP-TR-2022-0044
12. DISTRIBUTION/AVAILABILITY STATEMENT A Distribution Unlimited: PB Public Release			
13. SUPPLEMENTARY NOTES			
14. ABSTRACT Three Analytical Stories: 1. Recurrence 2. Convergent Cross-Sorting 3. Topological Data Analysis			
15. SUBJECT TERMS			
16. SECURITY CLASSIFICATION OF:		17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
a. REPORT U	b. ABSTRACT U	c. THIS PAGE U	SAR 23
19a. NAME OF RESPONSIBLE PERSON ALAN LIN			19b. PHONE NUMBER (Include area code) 227-7009



Discovering patterns in human-robot interaction: New tools for complex adaptive social systems

PI's: Andrea A Chiba, Janet Wiles, Gregory Funke

University of California, San Diego

AFOSR, June 4th 2019

Joint AFOSR-DSTG Program Summary

- **Project Vision**
 - **Discovering patterns in human-robot interaction: New tools for complex adaptive social systems**
- **USAF / DoD / Industry Relationship Highlights**
 - **Co-PIs:**
 - Prof Janet Wiles UQ Australia
 - Prof Andrea Chiba UCSD USA
 - Dr Greg Funke WPAFB USA
 - **DST links: Robert Bolio; Chris Best; Glenn Moy**
 - **Shared code + repository**
 - Matlab algorithms for TDA, stochastic filtering, cycle estimation, recurrence analysis, cross-sorting
- **Collaboration Synergy Highlights**
 - 2 students from UQ visited UCSD for 1 month (Nov 2018)
 - 1 student from UQ visited WPAB in Dayton (Nov 2018)
 - Monthly zoom with slides
- **Follow-on awards enabled by support from this program**
 - Fractional appointments on multiple grants
 - 1 Year IBM Funding for Leo Breston
- **Top Cited Papers**
 - Several papers in preparation
 - Toolbox Under Construction
- **Students**
 - David Ferris now PhD student
 - Eric Leonardis, ABD
 - Leo Breston, PhD Student
 - Scott Heath, Post-Doctoral Fellow



Three Analytical Stories:

Recurrence

Convergent Cross-Sorting

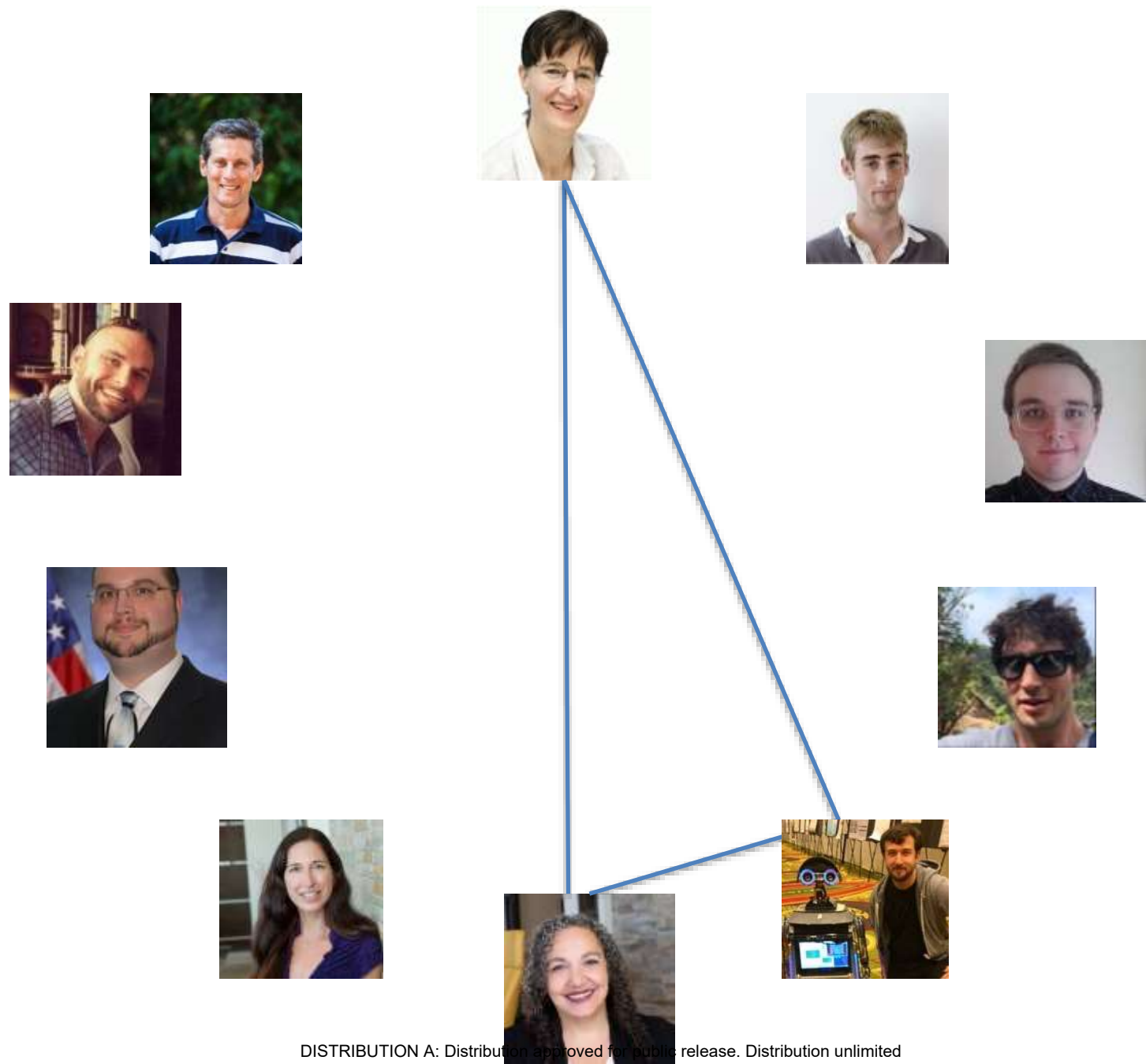
Topological Data Analysis



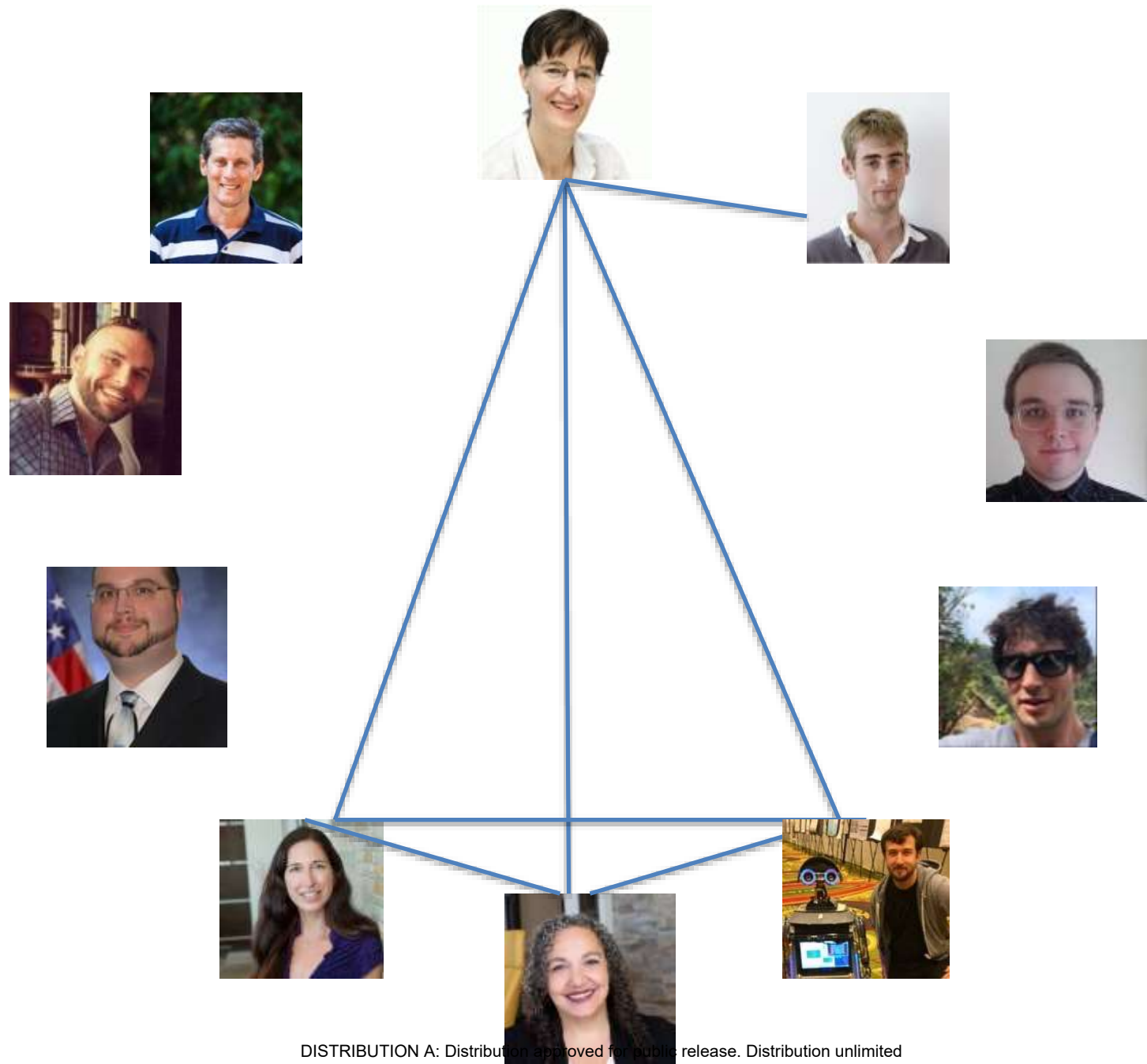
Brisbane, AU
San Diego, USA



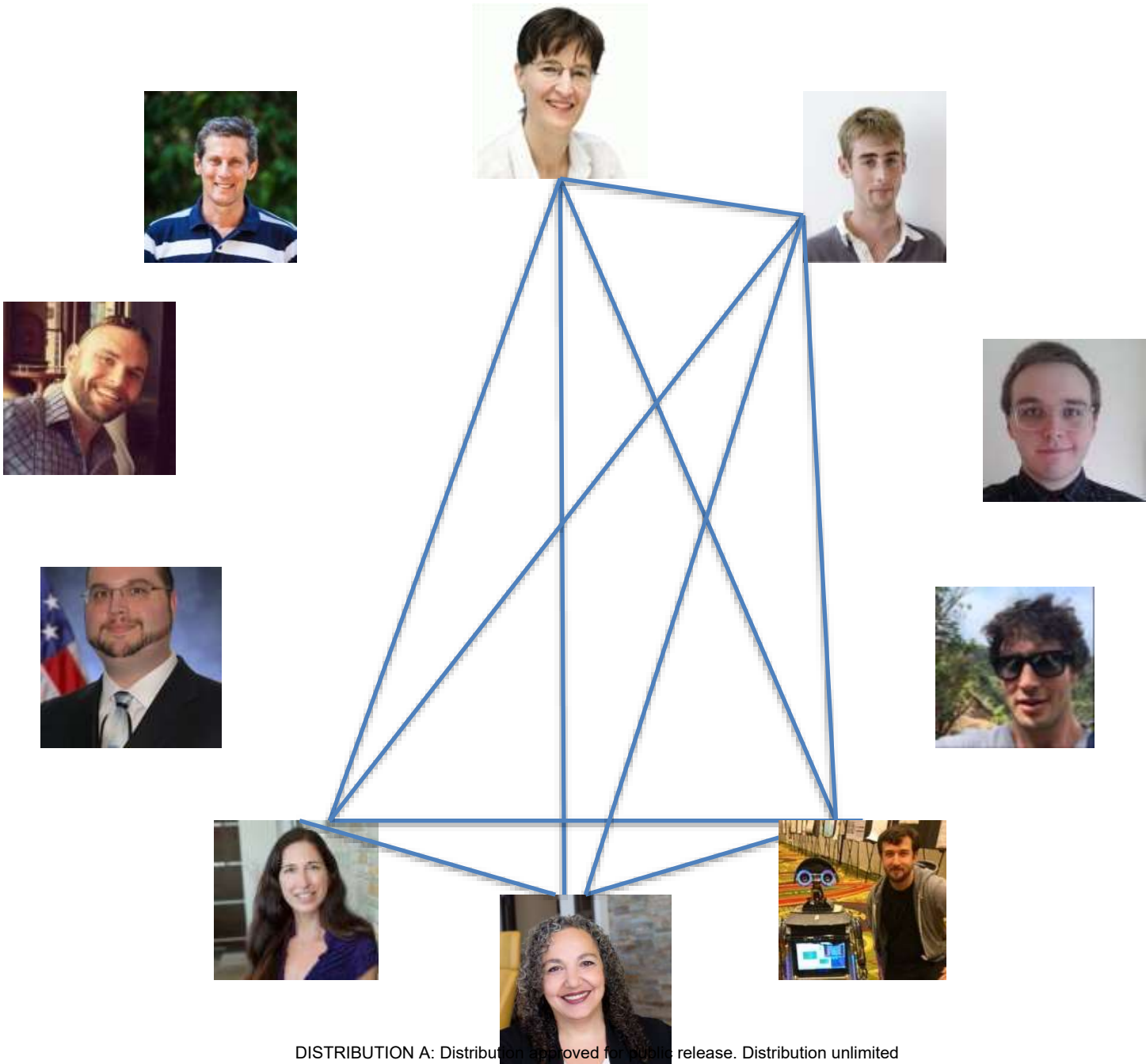
Dayton, USA



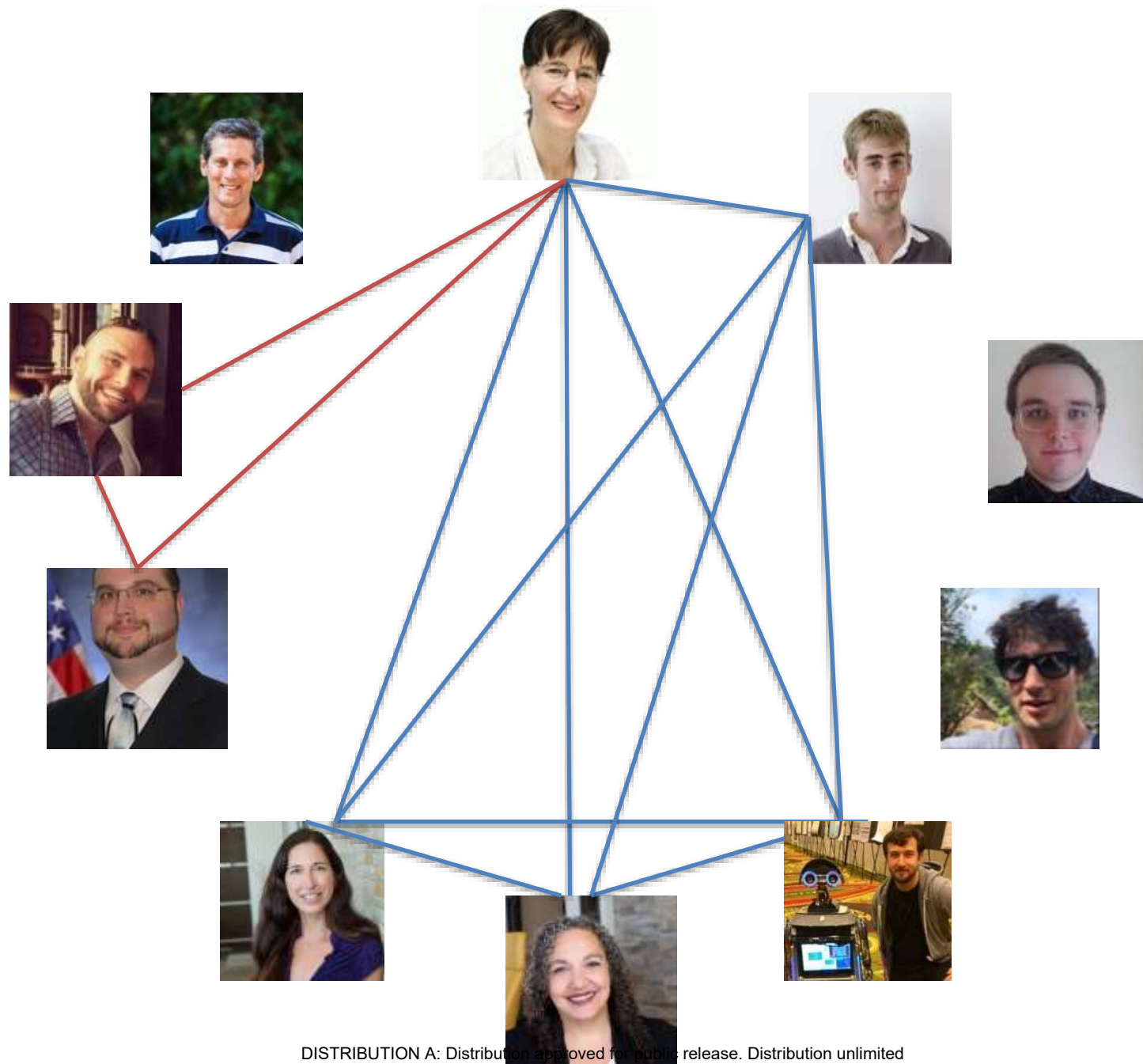
DISTRIBUTION A: Distribution approved for public release. Distribution unlimited



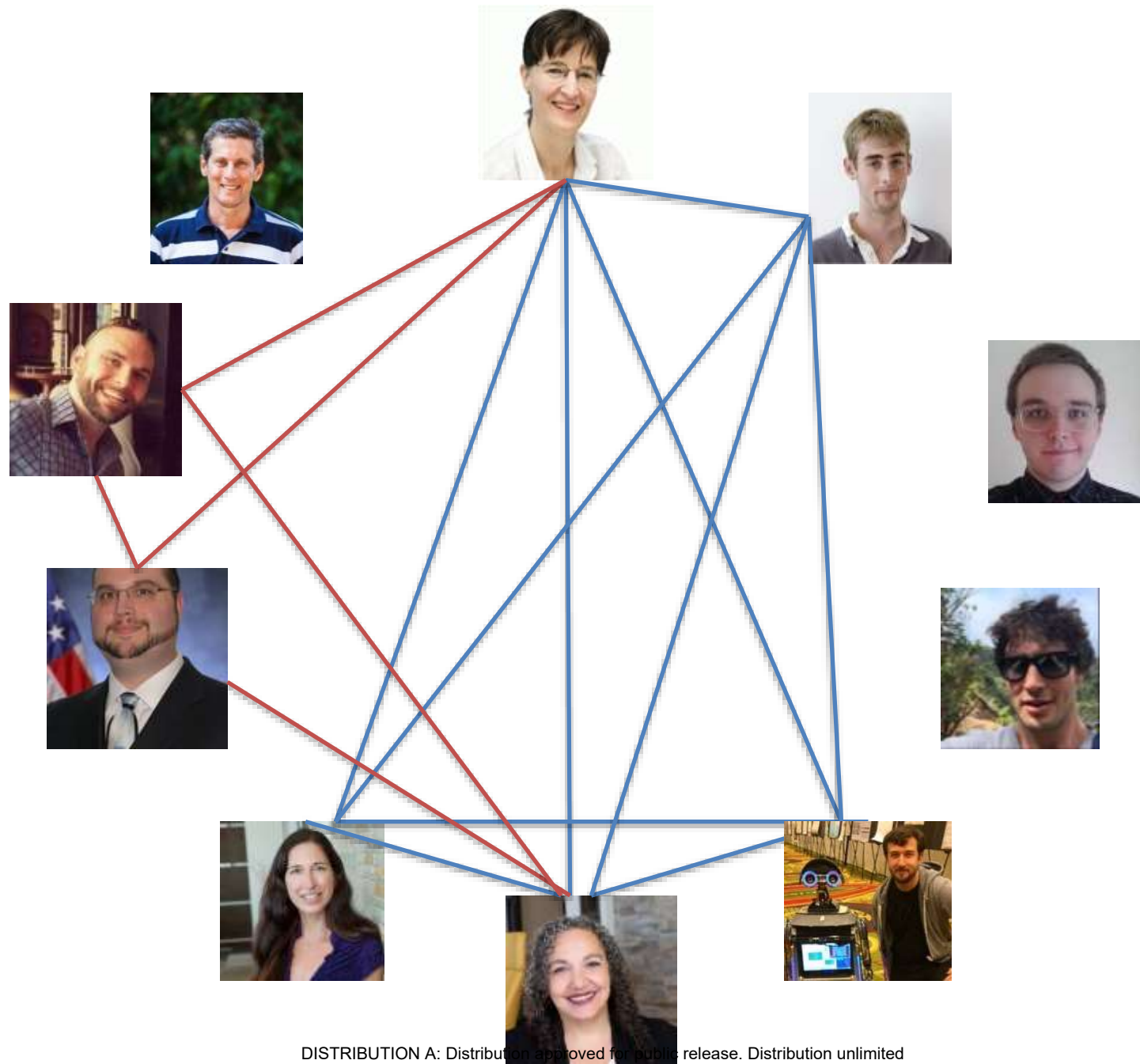
DISTRIBUTION A: Distribution approved for public release. Distribution unlimited



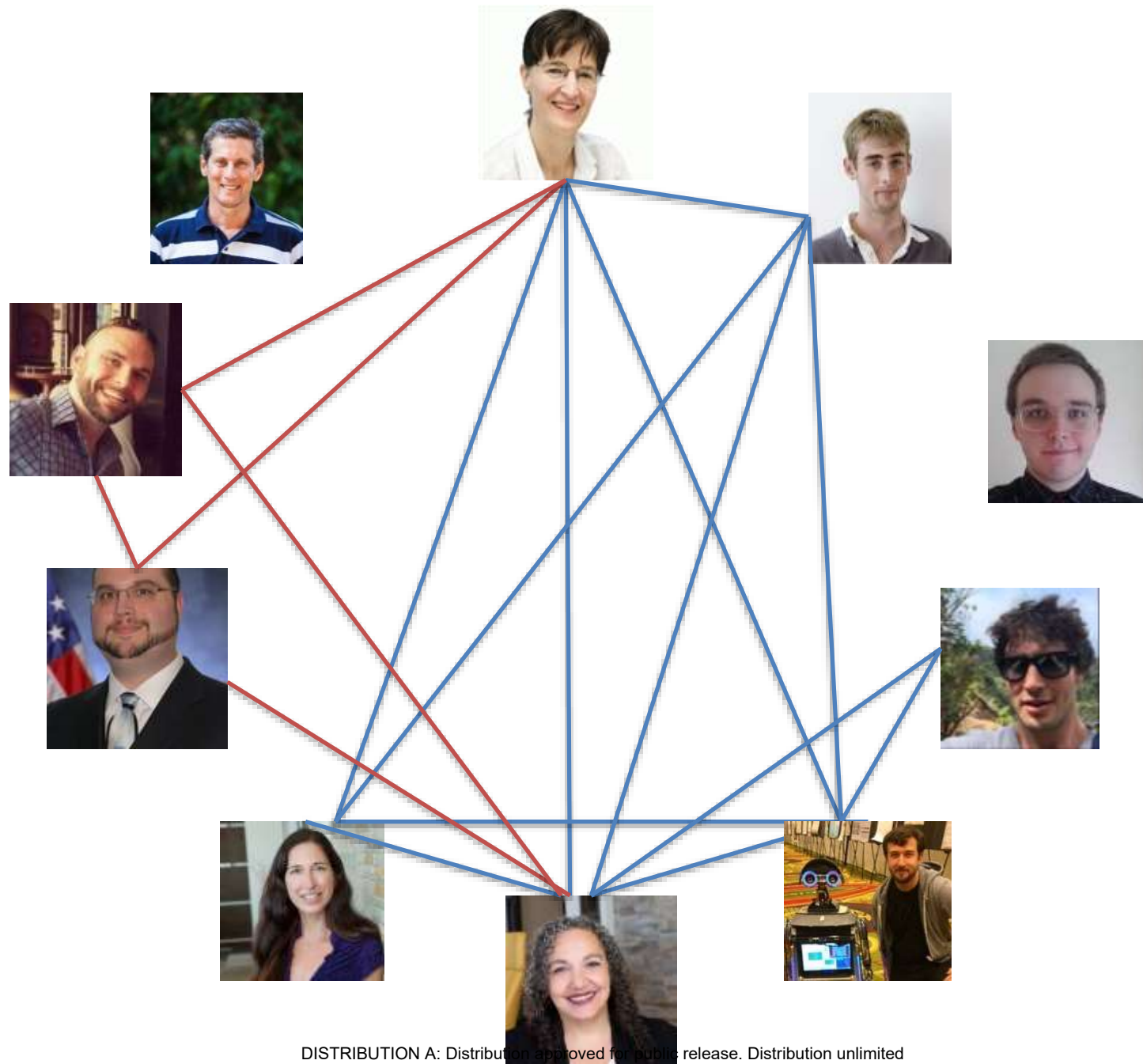
DISTRIBUTION A: Distribution approved for public release. Distribution unlimited



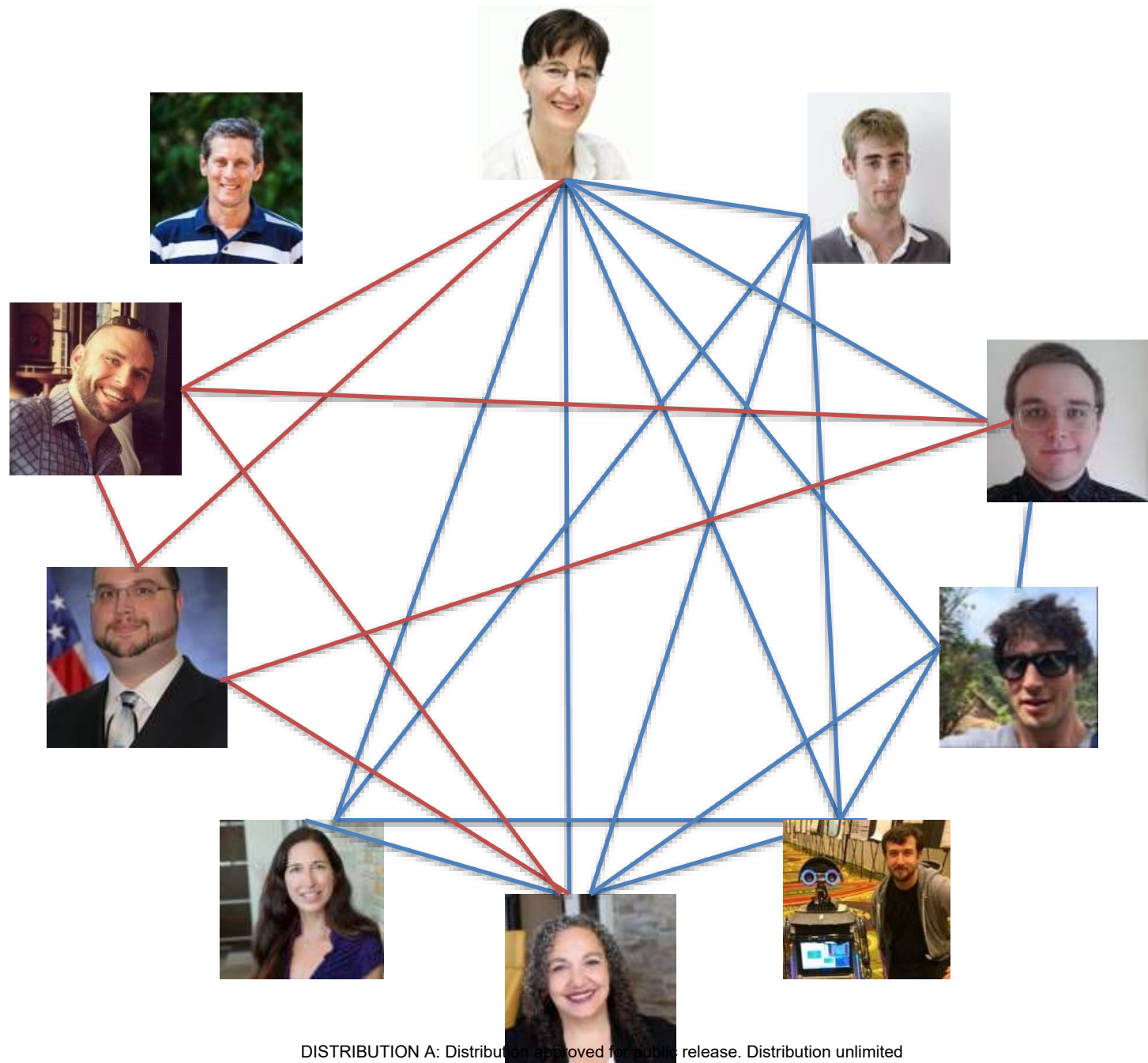
DISTRIBUTION A: Distribution approved for public release. Distribution unlimited



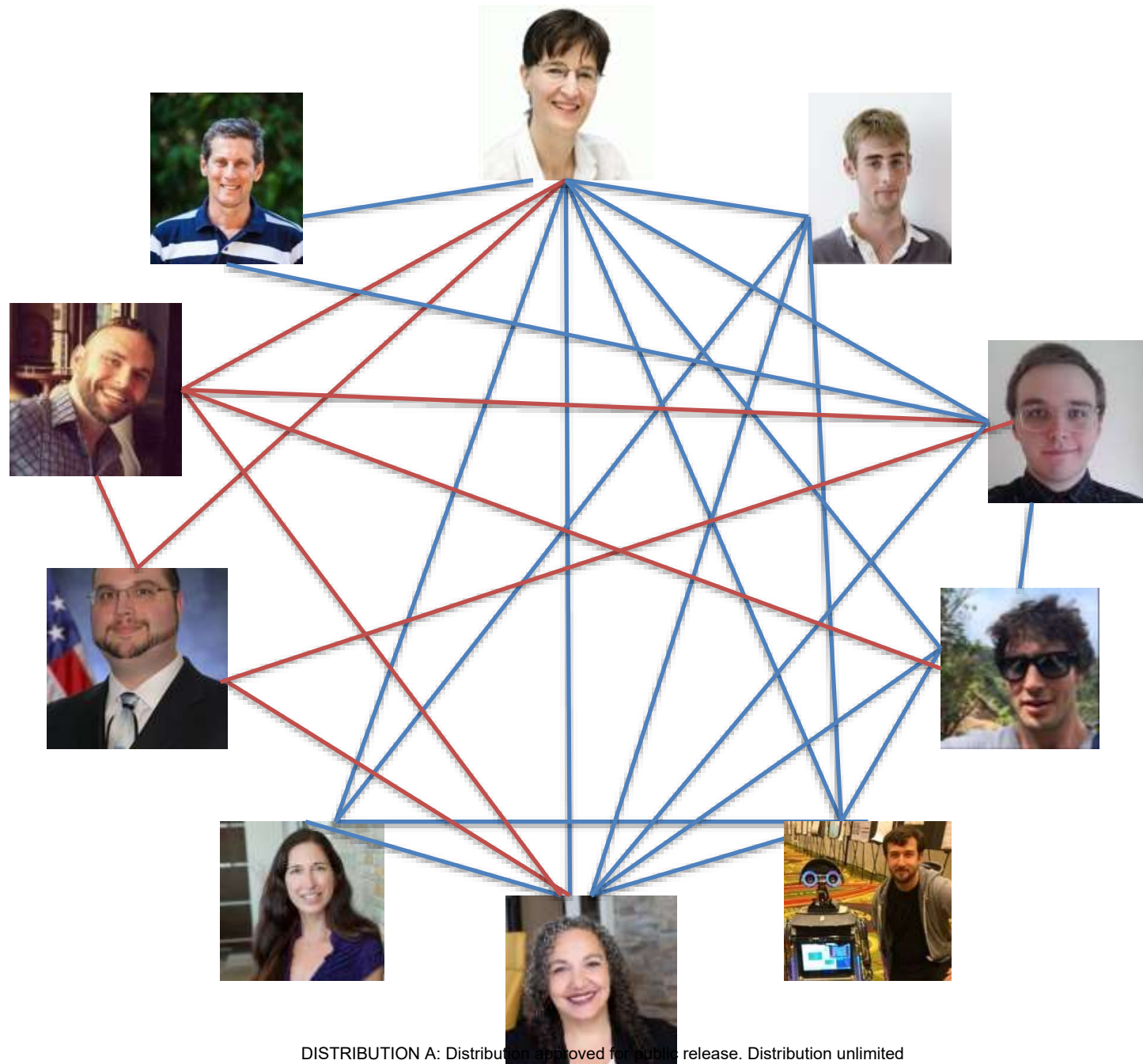
DISTRIBUTION A: Distribution approved for public release. Distribution unlimited



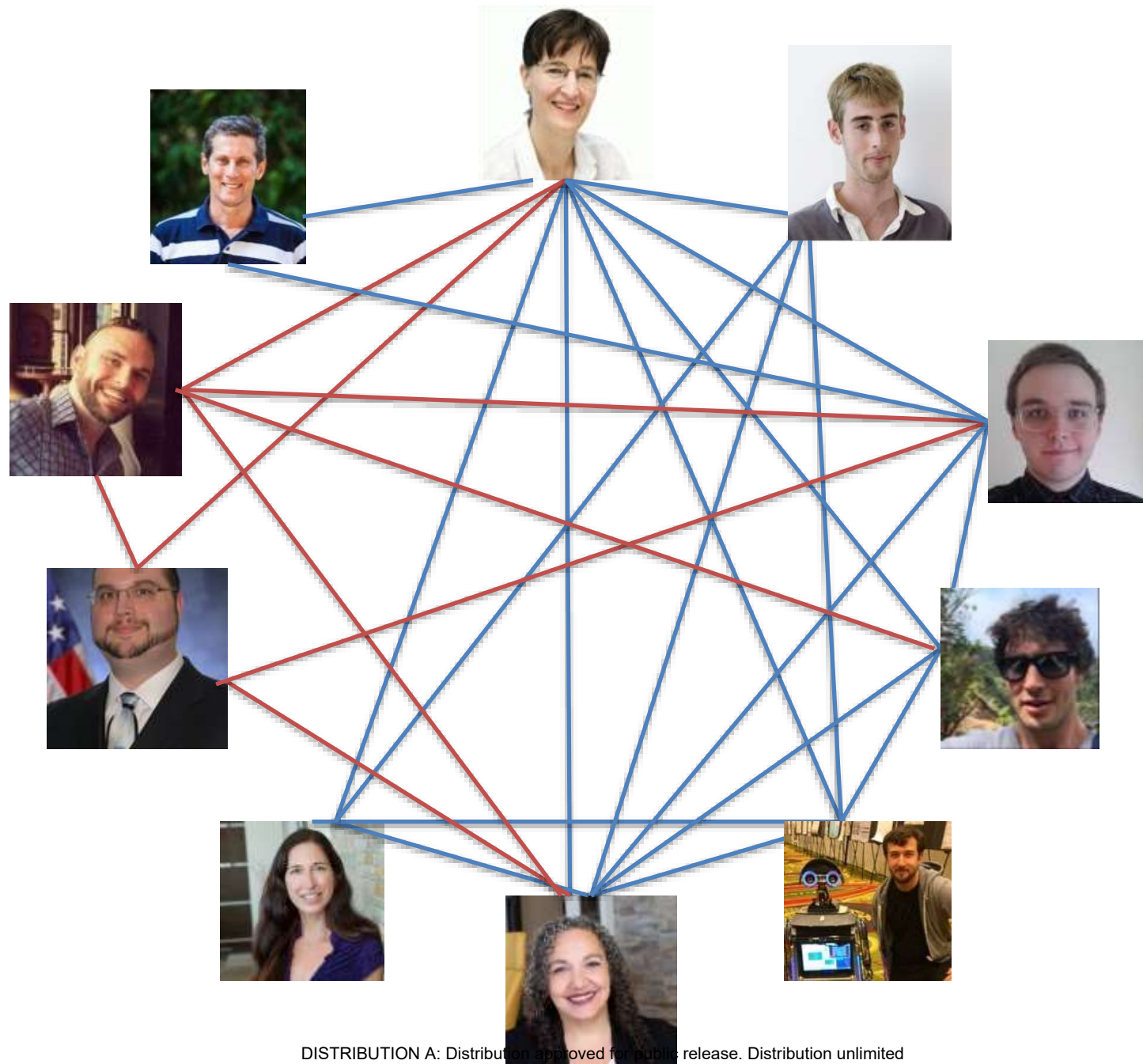
DISTRIBUTION A: Distribution approved for public release. Distribution unlimited



DISTRIBUTION A: Distribution approved for public release. Distribution unlimited

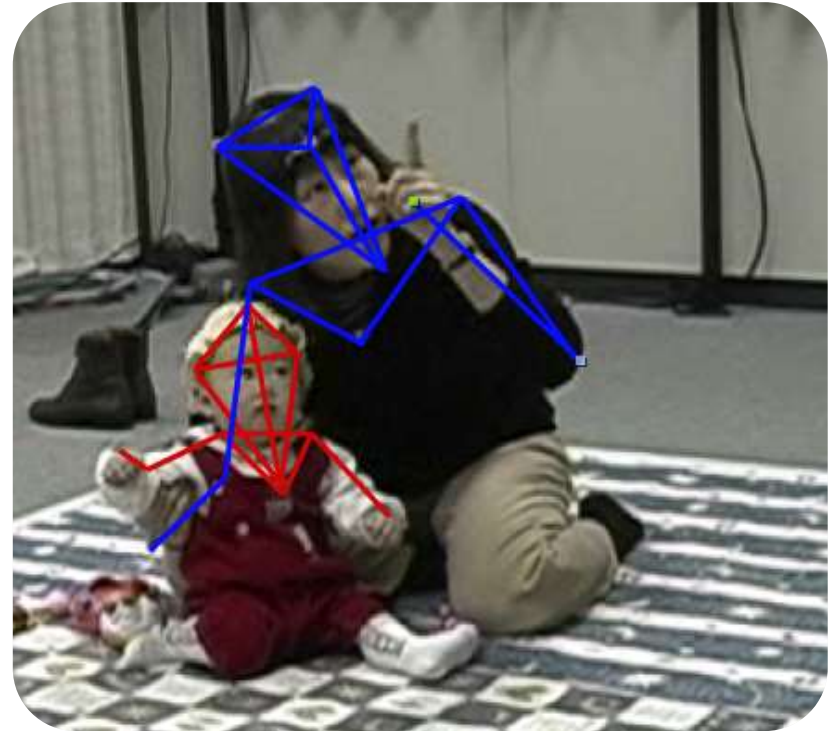


DISTRIBUTION A: Distribution approved for public release. Distribution unlimited



DISTRIBUTION A: Distribution approved for public release. Distribution unlimited

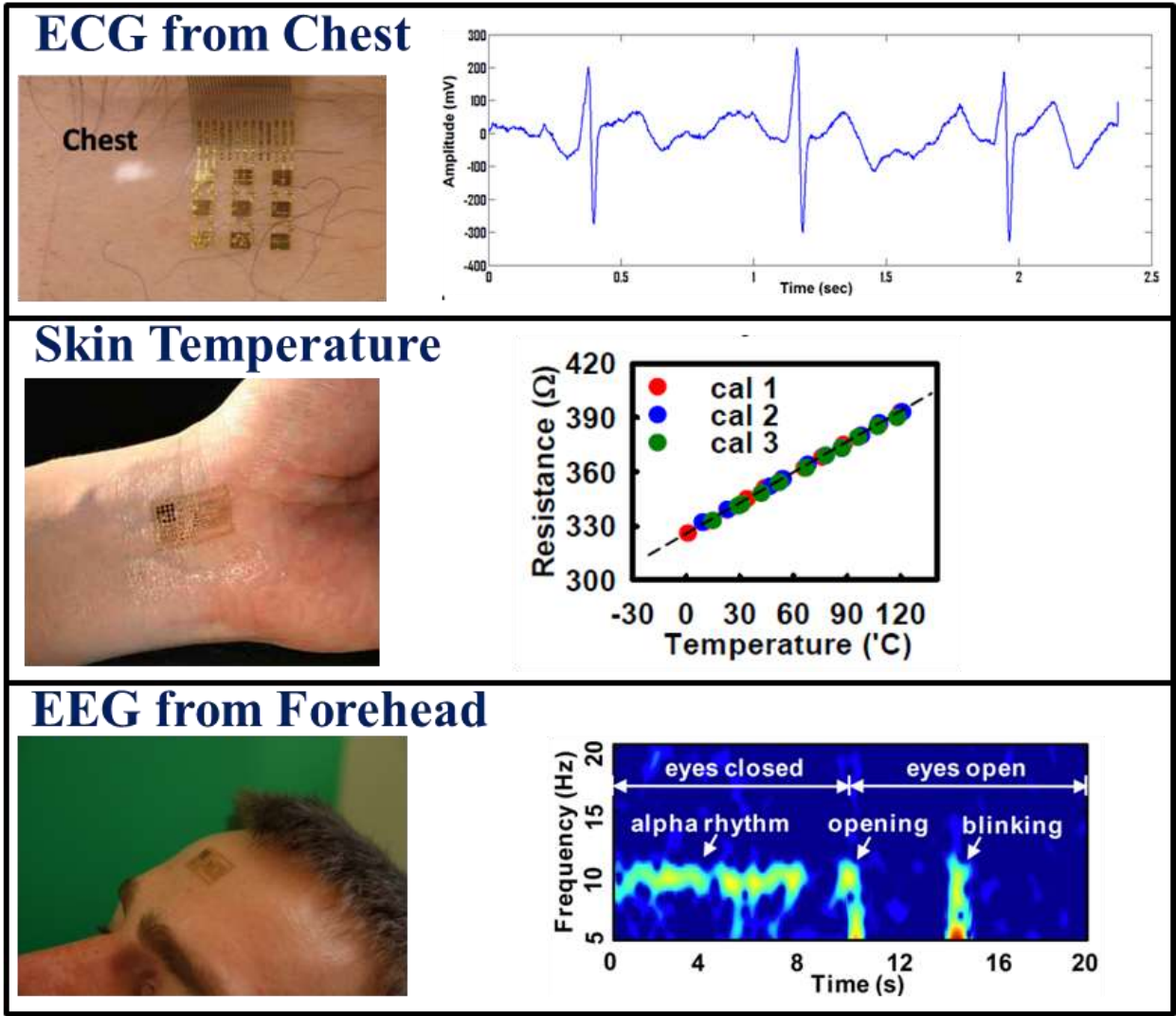
Our Learning is Socially Situated at the Outset



Temporal and Spatial Dynamics are Pervasive



We now have increasing power to measure inter and intra personal dynamics across time



Time is an organizing principle of the brain and body

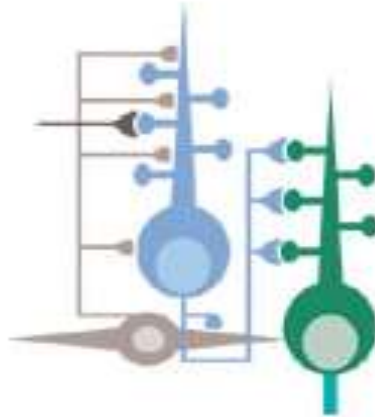
STDP



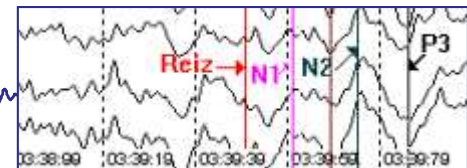
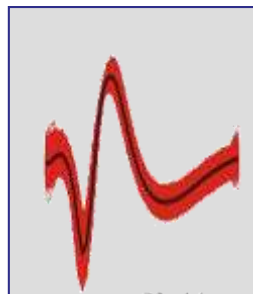
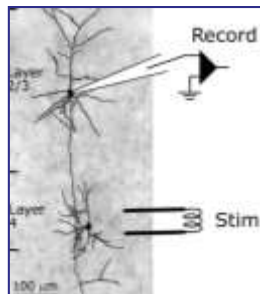
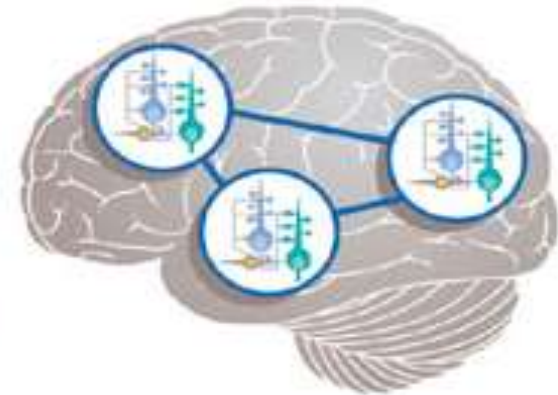
Spikes



Local Field Potentials



Cortical EEG



“Brain oscillators make reliable networks from “unreliable” elements (i.e. neurons).”

J. v Neumann



Recurrence Analysis

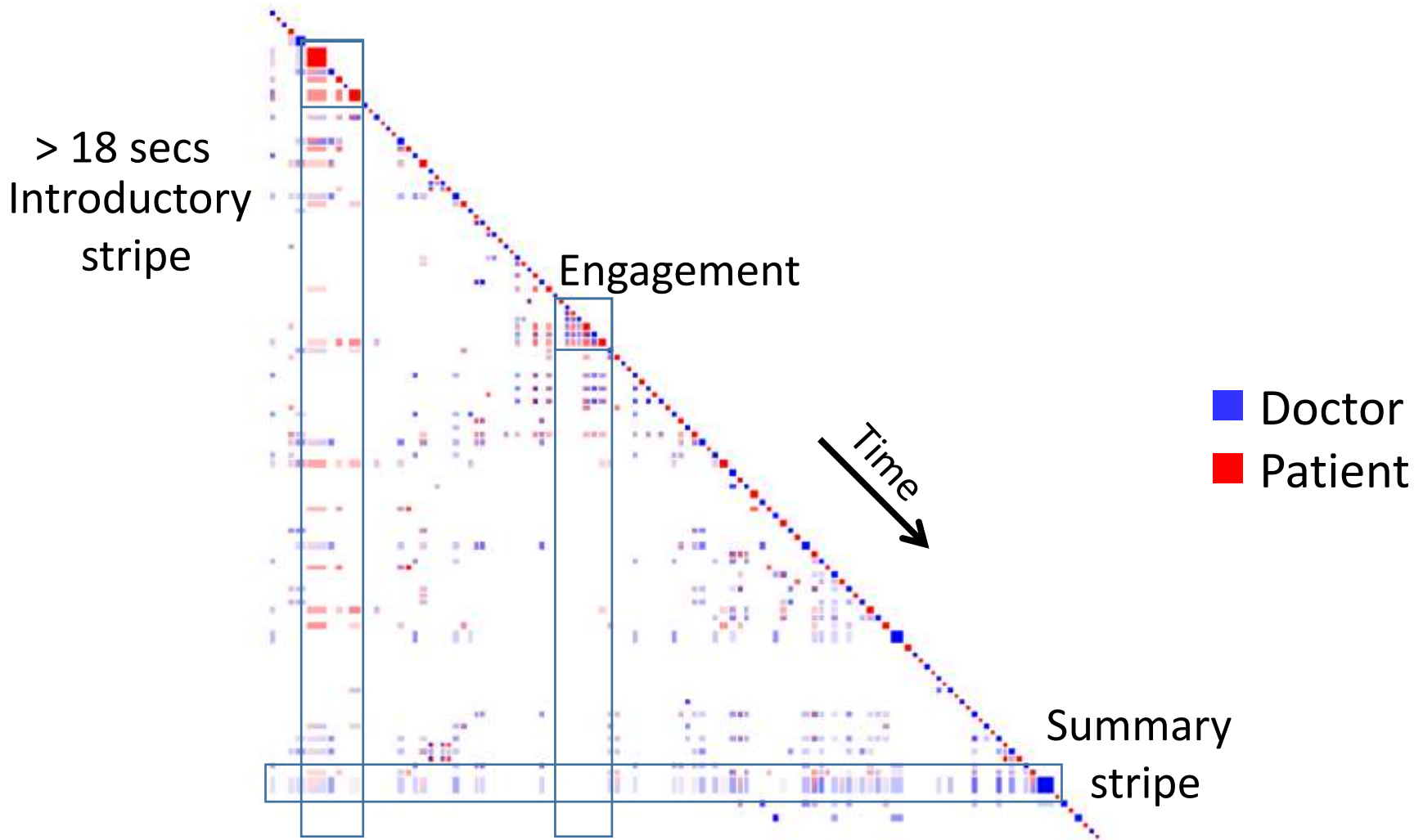
Eric Leonardis

UCSD Graduate Student, AFOSR

Dynamical Systems

- **Dynamical System:** A system whose next state only depends on its current state
 - Deterministic
 - All the variables of the system are dynamically/causally Coupled
- **Phase Space:** a geometric representation of the state of a dynamical system in which coordinates of the space are the systems components
- **Manifold:** The set of points in phase space traced out by the system

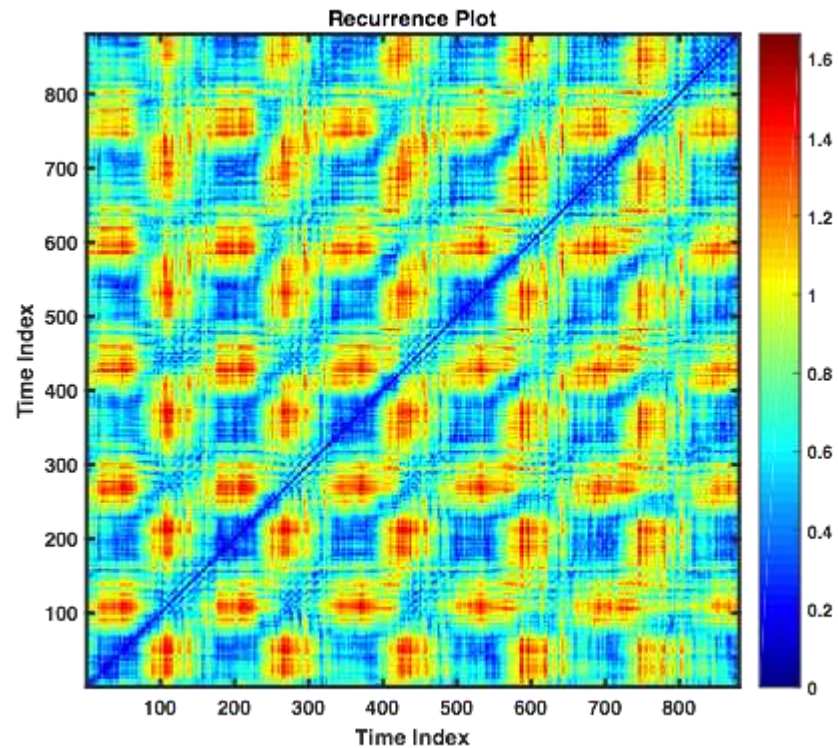
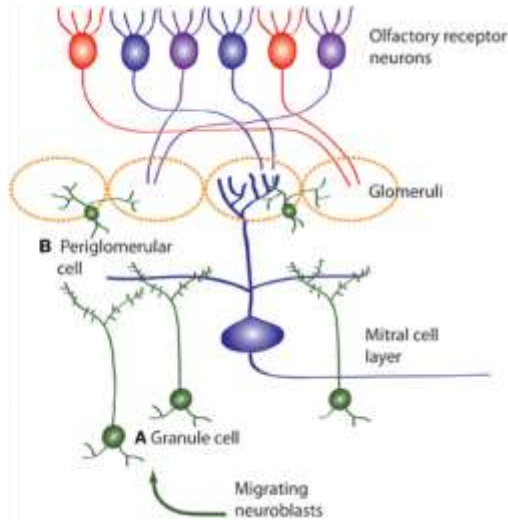
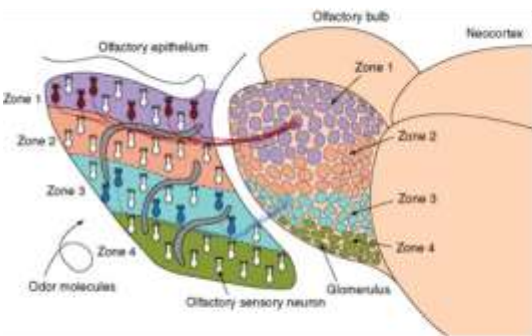
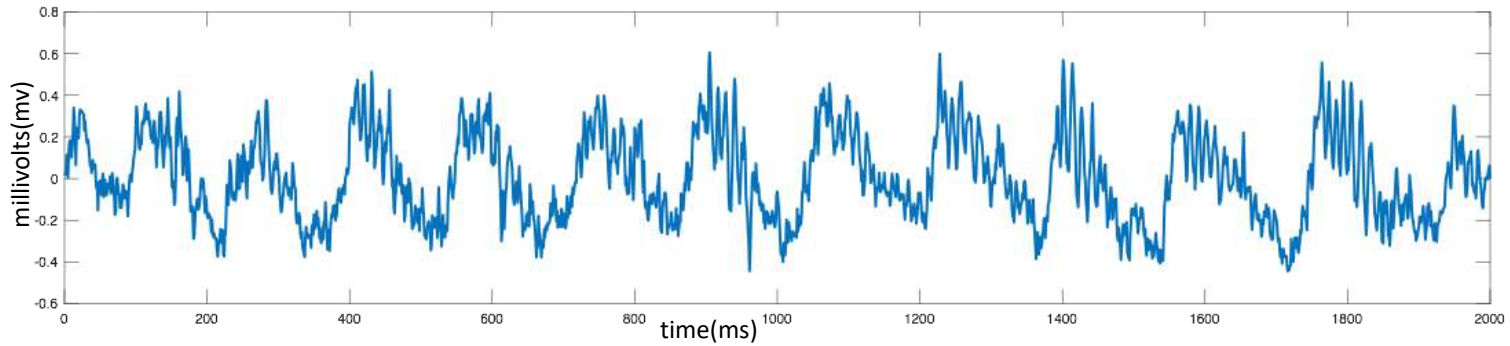
Recurrence Plot: Conceptual Recurrence in Conversation



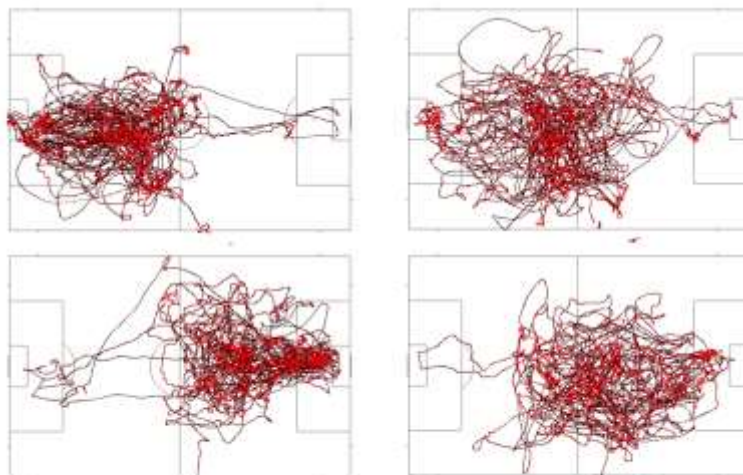
Daniel Angus and Janet Wiles

Doctor-patient interviews courtesy of
Marcus Watson, Queensland Health

Respiratory Rhythms in The Brain



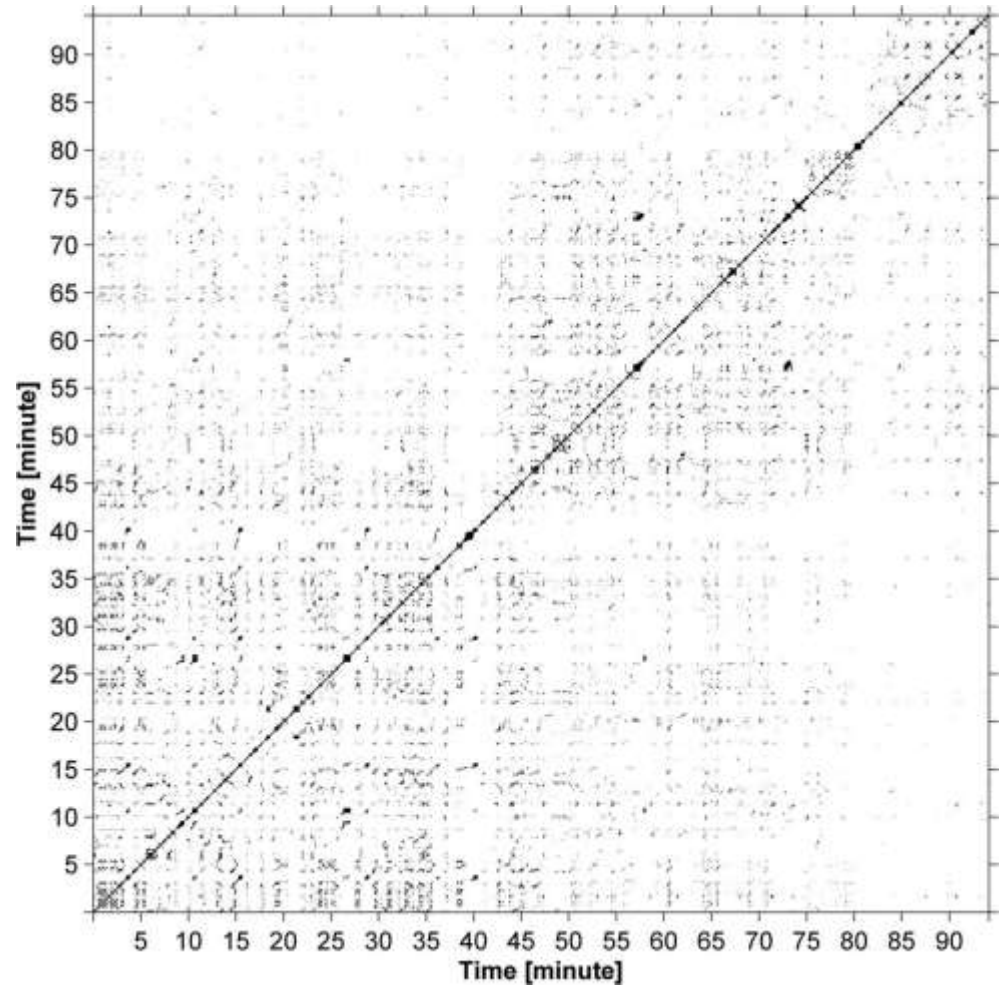
Future Directions: Modeling Team Sports As Complex Systems



(b) Defender.

(c) Midfielder.

Recurrence Plot of Soccer Position Data



Stöckl, M., Plüch, D., & Lames, M. (2017).

Pettersen, S. A., Johansen, D., Johansen, H., Berg-Johansen, V., Gaddam, V. R., Mortensen, A., ... & Halvorsen, P. (2014).

Causal Time Series Analysis

- Determining if one variable is a cause of another
 - Ubiquitous challenge in almost all fields of science
- Standard Method: Granger Causality
 - If x predicts y then x is a cause of y
- Assumptions
 - Linear
 - Separable
 - Stochastic
- Problem
 - Many natural systems do not fit these assumptions
 - Better modeled by Dynamical Systems
 - **Need a analysis method that is compatible with these systems**