UNOBTRUSIVE BEHAVIOURAL MONITORING VIA THE INTERACTIONS OF DAILY LIVING

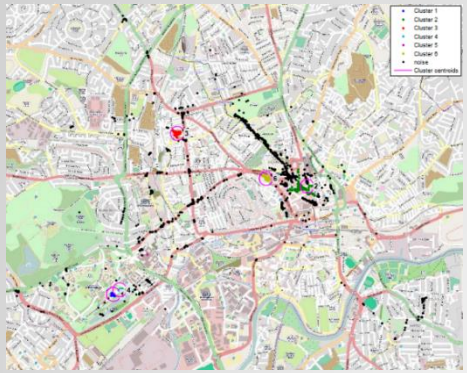
John Crowe, EEE
Mercedes Torres Torres, CS

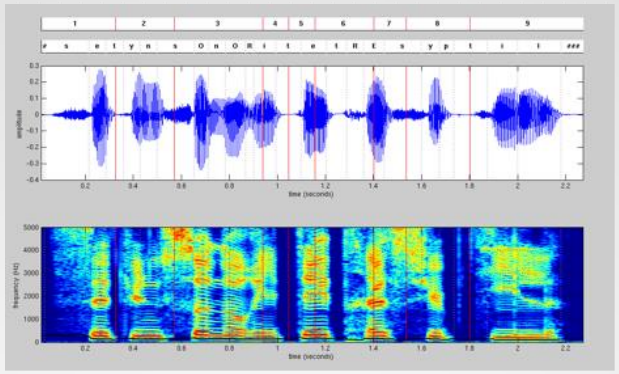
Shazmin Majid, IMH
Debbie Butler, IMH

University of Nottingham

IN THE DEVELOPED WORLD…

- "Living" entails ***interacting*** with utilities and devices:





OBSERVING 'BEHAVIOUR'

- Monitoring these ***interactions*** (directly or by proxy) allows changes in "behaviour" to be observed.

- For people with mood disorders this information could be used to:
  - facilitate development of self-awareness of triggers
  - provide early warning signs
  - enable patients to take control of their condition
  - complement data obtained from 'wearable technology'

PROPOSAL

- To explore four mechanisms of interaction via the literature and liaison with relevant parties:
  1. Utility and device usage
  2. Car usage and driving style
  3. Banking and Card transactions
  4. Monitoring via mobile phone

- For each mechanism, consider technical, legal, ethical, social and usability challenges.
- To explore how data obtained through each mechanism can be combined to enable accurate monitoring of changes in behaviour

FUNDING FROM NEWMIND

- Support for Research Assistant for approx. 2.5 months to review literature, engage with relevant staff at UoN and other institutions to explore these ideas

- Two researchers:
  - Shazmin Majid RA in Institute of Mental Health, UoN
  - Tom Partridge PhD student, Fac. of Engineering, UoN

- Travel budget to visit UK universities to discuss project with those exploring related ideas

DELIVERABLES - *AS PROPOSED*

1. Reports on each of the four means of monitoring – with sections on :
    1. Technical difficulty
    2. Legal, ethical, social concerns / solutions
    3. User acceptability

2. Report on other possible means of monitoring (in the same spirit) and how these may complement wearable technologies and output from other projects (eg EPSRC funded SPHERE, HAT).

    [Sensor Platform for HEalthcare in a Residential Environment]

    [Hub of All Things]

3. Draft proposal to build a demonstrator system of this proposed method of monitoring – informed by our findings

PATIENT & PUBLIC INVOLVEMENT

- Workshop at IMH on: 21/09/2017
  - 12 participants
  - Output from workshop included: suggestions, concerns and uses.
  - Suggestions
    - Adherence to medication
    - Bed monitor – eg. Beddit
    - System could 'encourage' as well as 'warn'

PATIENT & PUBLIC INVOLVEMENT

- Concerns
  - Who will own / have access to data
  - Knowledge of being monitored could affect behaviour or trigger episodes
  - Users must have control over system

- Use
  - Could carers contribute data
  - Timescales re. data processing / reporting
  - Could it reduce appointments

PATIENT & PUBLIC INVOLVEMENT

- The success of workshop led to the development of a questionnaire to explore views on :
  - different forms of monitoring
  - who could / should be permitted access to data
  - mobile phone usage
  - use and experience of wearable technologies
  - wearables vs unobtrusive
- The questionnaire is currently awaiting UoN ethical approval

EXTERNAL ENGAGEMENT

- Hub-of-All-Things (Prof Irene Ng, University of Warwick)
  - "The Hub of All Things (HAT) is a technology designed to help the Internet exchange and trade personal data. HATs are 'private data accounts' that let anyone store their personal data for themselves, so that we don't have to rely on governments or corporations to store it for us."
  - Potentially provides a mechanism for collecting, aggregating, processing data

EXTERNAL ENGAGEMENT

- Affectech (Prof Corina Sas, University of Lancaster, 20/11/17)
  - Marie Sklodowska-Curie European Commission training network
  - "Personal technologies for affective health – Cutting-edge technology transforming our understanding of common mental health disorders"rs

- SPHERE - Sensor Platform for HEalthcare in a Residential Environment
  - University of Bristol
  - Contacted – date for visit to be confirmed

INTERNAL ENGAGEMENT

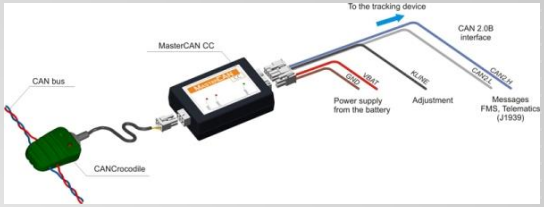
- Biomedical Research Centre (BRC) - Mental Health Theme
  - MindTech HTC (to become MindTech MedTechCentre)
    - PPI support
  - Computer Science: Computer Vision Lab, Horizon Research, Mixed Reality Lab
    - Depression monitoring via audio-visual information.
    - Privacy Ideation Cards to inform design in accordance with GDPR
    - DataBox to create designs that process relevant information locally, preserving the privacy of users.
      - (non-cloud based 'version' of HAT)

UTILITY AND DEVICE USAGE

- Via utility meters and electromagnetic emissions.
- FINDINGS SO FAR
  - Research has shown that information about eating & sleeping routines can be extracted from power consumption patterns
  - Non-intrusive power usage monitoring (NIALM)
    - Currently, no complete (ie for all appliances) NIALM solution is suitable
  - REDD – reference energy disaggregation dataset
    - Freely available for algorithm development
  - Water usage
    - Meetings with Quensus (Notts-based water-consumption monitoring company)
  - 'Smart' device usage via their WiFi signals

CAR USAGE AND DRIVING STYLE

- Via the information distributed across the Controller Area Network (CAN) bus
- FINDINGS SO FAR
  - Research using smartphones to detect driving styles and behaviours exists
    - That could supplement CAN bus info from OBD-II on-board diagnostic port
  - We have developed an app to map quality of road surface
    - Automatic data download when in WiFi range
  - Apps to detect entry into a car
  - Devices to connect to CAN bus are widely available – but possible issues if these are used in an unintended manner (CE marking etc)



BANKING & CARD TRANSACTIONS

- Via read-only access to account usage
  - Spend patterns expected to be linked to behaviour.
  - This information is already collected and used.

- FINDINGS SO FAR
  - Payment Service Directive (EU) (PSDII)
    - Will apply from 13th January 2018
    - This will give 3rd parties (Account Information Service Providers (AISPs)) access to financial transactions
    - These could be analysed for changes in behaviour, making our project VERY TIMELY.

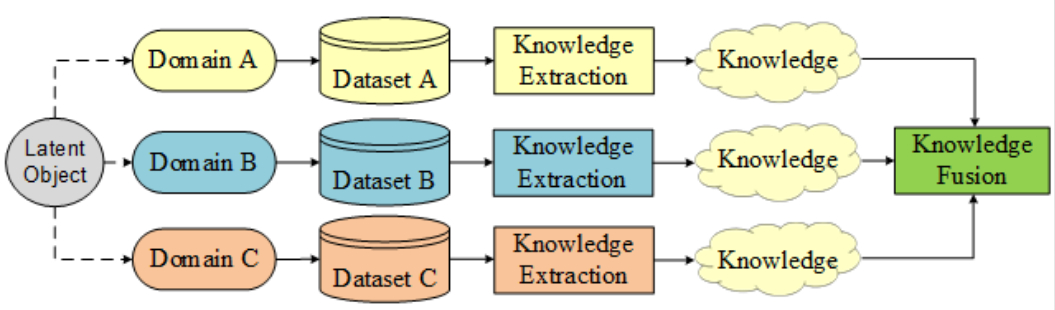
MONITORING VIA MOBILE PHONE

- Via GPS location and speech analysis from mobile phone

- FINDINGS SO FAR
  - Papers on inferring behaviour from location data
  - Location via GPS and Google location (or similar)
    - eg proximity to WiFi nodes
  - BlueTooth connections much less useful than they were
  - Speech analysis possible – also some work on using INS data re 'speech' patterns
    - PureTech Health - voice patterns for multiple health conditions
  - Work exists suggestion head motion during speech may be indicator of mental health condition

DATA ANALYSIS AND MINING

- Via cross-domain knowledge data fusion
- FINDINGS SO FAR:
  - Data considered: multiple modalities: each with different representation, distribution, scale, and density. Each provides (connected) knowledge:



  - Papers reviewed on fusion at levels:
    - Stage: datasets loosely coupled. No consistency.
    - Feature: all datasets treated equally, (i.e. concatenating). That is then used for clustering/classification.
    - Semantic: datasets as different views of object/person. Focus: understanding insight and relations of each dataset.

MACHINE LEARNING

- Via deep learning
- FINDINGS SO FAR
  - Deep learning involves little pre-processing of raw data.
  - Papers reviewed on successful architectures:
    - Hourglass or Recurrent networks: require thousand or millions of samples from the same source. Currently not suitable for our purposes.
    - Siamese networks: specialised in combining multi-source information.
    - LSTM networks: allow temporal data as input.
    - Small-sample CNNs: Optimised to small sets of data by combining CNNs and linear regression.

FOLLOW-ON PROPOSAL

1. Construct a demonstrator that will collect data via a subset of methods
   - Sensors – generally will exist
   - Need to provide common hard/software interfaces (eg API) to central repository …
   - … probably the users' HATs
2. Needs to be extensible
   - New sensors added efficiently via common interface
3. Develop in partnership with potential users
   - Demonstrate data collection in small pilot study

FOLLOW-ON PROPOSAL

4. Explore data fusion and machine learning with small subset of data collected
5. Consider how to include 'wearable' information & other information (eg Twitter & FaceBook usage – provided by HAT)
6. Home data processing & transfer (of restricted data set?) to 'hospital' data centre
   - Immediate feedback to user?
7. Processing of data in 'hospital' to inform clinician / generate alerts