Damage Mapping of April 2015 Nepal Earthquake using Small UAV

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Outline

NSET presents
1. Overview of earthquake damage
2. Background of the proposal
3. Original Plan
4. UAV regulation and permission

NIED presents
5. Survey report
   Sankhu, Chautara (Heli), Langtan (UAV), Charikot (Heli)
   Khokana, Bungmati, Bhaktapur, Bhainsepati (UAV)
6. Discussion
7. Conclusion
Overview of earthquake damage

Intensity Map based on USGS, 2015
April 25 Gorkha Nepal Earthquake
Background of the proposal

NSET's damage mapping and motivation

- Building damage survey – in earthquake hit areas (200,000 buildings),
- Rapid assessment is required quickly for planning purpose – relocation, shelter, displace, evacuation sites identification, possible open spaces etc.
- Proposed for UAV survey for planning and quick extract of data using UAV, low cost, high resolution information of damaged area.
- Building damage assessment with oblique photographs – identification of damage grade
- Proposed low-altitude aerial photo surveys
## Going Low Altitude for High Resolution

<table>
<thead>
<tr>
<th>Camera On</th>
<th>Ground Altitude</th>
<th>Resolution</th>
<th>Can identify damage level down to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite</td>
<td>300 km-</td>
<td>1 - 10m</td>
<td>5 : Total Collapse</td>
</tr>
<tr>
<td>Plane/Heli</td>
<td>300m-3km</td>
<td>0.1 - 1m</td>
<td>4 : Heavy Damage</td>
</tr>
<tr>
<td>UAV</td>
<td>30m-300m</td>
<td>3 – 30 cm</td>
<td>3 : Moderate Structural/High Non-structural Damage</td>
</tr>
<tr>
<td>Pole</td>
<td>3m-10m</td>
<td>0.3 – 1 cm</td>
<td>1 or 2 : Non or Minor Structural Damage</td>
</tr>
<tr>
<td>Human</td>
<td>1.5 m</td>
<td>0.1 - 1cm</td>
<td>1 or 2 : Non/Minor Structural Damage</td>
</tr>
</tbody>
</table>
Our UAV is a fixed-wing plane

Long-range and Safety

Flight Controller: APM 2.6
Wing span: 118cm
Cruise Speed: 60km/h
Flight time: 30 min (30km)

Catch net
Safety is of paramount importance to fly UAVs over inhabited areas, not to make another disaster.

One crash every hundred flight is unavoidable in current technology of small UAV.

Less chance to injure people because:
1. Made of soft material
2. Break itself to absorb shocks
3. Propeller is facing rear
4. Glides to fall in case of trouble
5. Less flights due to longer range

More chance to injure people because:
1. Made of hard and sharp material
2. Not designed to break
3. Propellers are exposed
4. Simply falls in case of trouble
5. More flights due to shorter range

Fixed-wing plane

Multicopter
Hand Launch and Net Catch

Take-off

Landing
An example mission in Bhainsepati, Lalitpur

2 km² area in one flight of 22km (22 minutes) at 150m ground altitude, 100m lane interval
Original Plan

Central 100 km² Area of Kathmandu Valley to be surveyed by 2km² x 50 flights in non-rainy 10 full working days

Jun 1- UAV permission
Jun 15- Pilot survey in Bhainsepati
Jun 20- Full-scale survey in Kathmandu Valley
Jul 31 Completion of UAV survey in Central KV
Aug 31 Preliminary damage map of a part of central KV
1. Submit documents to CAAN
   - A Filled form with UAV details
   - Request Letter
   - Copy Map of Operation area/plan
   - No Objection, Recom’ tion from Concerned Authorities
   - Security Clearance

2. Process from CAAN
   - Permission from MoHA,
   - Permission from Nepal Army, Nepal Police, Armed Police Force

3. Submit Flight details to CAAN
   - Permission from MoIC
   - Permission from TIA

General Permission

Individual permission

Flight under coordination with local police, and presence/ consent/ liaison with govt. CAAN

MoHA on behalf of GoN, issued UAV Flight Procedure, 2015
<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2015</td>
<td>NIED-NSET-KVDA collaboration</td>
</tr>
<tr>
<td>May 31, 2015</td>
<td>Approached to KVDA</td>
</tr>
<tr>
<td>Jun 1, 2015</td>
<td>JICA Letter to KVDA</td>
</tr>
<tr>
<td></td>
<td>Letter to MoUD by KVDA –</td>
</tr>
<tr>
<td>Jul 16, 2015</td>
<td>Request from MoUD to MoHA, MoD, MoCTCA</td>
</tr>
<tr>
<td></td>
<td>Responses from Security forces –</td>
</tr>
<tr>
<td>Aug 18, 2015</td>
<td>Response from MoUD to KVDA</td>
</tr>
<tr>
<td>Oct 28, 2015</td>
<td>Response from CAAN</td>
</tr>
<tr>
<td>Nov 21, 2015</td>
<td>Response from MoIC</td>
</tr>
<tr>
<td>Dec 4, 2015</td>
<td>Permission from MoHA</td>
</tr>
<tr>
<td>Feb 22, 2016</td>
<td>Final Permission from CAAN to KVDA (before 6AM)</td>
</tr>
<tr>
<td>Jun 7, 18, 19, 2016</td>
<td>Flights in Khokana, Bhakutapur, and Bhainsepati</td>
</tr>
</tbody>
</table>
UAV was finally allowed in KV, but only before 6AM.

To avoid plane bird-strike, because,
1) Birds are surprised by UAV to fly,
2) It takes one hour to settle down,
3) The first flight of TIA is at 7AM.

Sunrise in Kathmandu
Jan 6:56  July 5:18
Feb 6:42  Aug 5:34
Mar 6:13  Sep 5:49
Apr 5:39  Oct 6:04
May 5:15  Nov 6:25
Jun 5:08  Dec 6:47
(on 15 of the months)

Only one flight in May, Jun, and July is possible.
Our UAV flight path was tangled. Going nowhere.

We had to switch the target to study technical feasibility of quick damage mapping applicable to Nepal for future disasters by

1. Experimental UAV survey in KV, and outside KV
2. Helicopter survey in Sankhu, Chautara, Charikot
3. Proposing alternative methodology
4. UAV Seminar and Training for the future
Original UAV photos were used by Ohsumi, et al (2015), “Investigation of building damage and ground truth verification of satellite data from the Kathmandu Valley related to the 2015 Gorkha Earthquake, Earth, Planets and Space: submitted.”
Chautara Heli Survey

Original Oblique Photo

3D Model (DSM)
First UAV survey, October 2015

J-Rapid Langtang project by Nagoya Univ. and Kathmandu Univ.

Kyanjing Gompa
UAV survey in Langtang, October 2015
Heli survey in Charikot, March 2016 for topo mapping

To assess topography effects on damage where NSET made damage survey on the ground
Charikot DSM to be compared with damage

Mar22, 2016
DSM in great detail

Nepal 1/25,000 Charikot

Heli DSM (500m AGL)

Enables to identify slope and curvature in great detail to assess topo hazards.

GCP measurements (accurate coordinates) are not necessary for the purpose, i.e., no need to wait for more detailed topo-sheets published by the mapping agency.
2nd UAV survey, June 7, 2016
Khokana and Bungmati, Lalitpur
AM 5:30 – 6:00

Take-off

Landing

Take-off and landing
Khokana and Bungmati UAV photos from 100m AGL

Jun 7, 2016, AM 5:30-6:00

Khokana

Bungmati
To be compared to the damages right after the earthquake Jun 7, 2016

Ground truth

Fig. 7.4 Survey of damage extent for every house in Sankhu and Khokana.5-8

<table>
<thead>
<tr>
<th>EMS-Level</th>
<th>EMS-Level</th>
<th>EMS-Level</th>
<th>EMS-Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2-3</td>
<td>4</td>
</tr>
<tr>
<td>RC</td>
<td>67</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>%</td>
<td>94%</td>
<td>0%</td>
<td>6%</td>
</tr>
<tr>
<td>BC</td>
<td>54</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td>%</td>
<td>74%</td>
<td>0%</td>
<td>23%</td>
</tr>
<tr>
<td>BM Well</td>
<td>7</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>%</td>
<td>64%</td>
<td>0%</td>
<td>36%</td>
</tr>
<tr>
<td>BM</td>
<td>39</td>
<td>3</td>
<td>75</td>
</tr>
<tr>
<td>%</td>
<td>27%</td>
<td>2%</td>
<td>52%</td>
</tr>
</tbody>
</table>
UAV survey, June 17, AM5:30-6:00, 2016
in Bhaktapur

0.8 km x 1.6km core area of the city,
100m AGL, 50m lane interval,
30km flight distance, in 30 minutes

Take-off and Landing
UAV survey, June 17, AM 5:30-6:00, 2016
in Bhaktapur

Cloudy weather

G0032270.JPG  G0032271.JPG  G0032272.JPG  G0032273.JPG
G0032274.JPG  G0032274.JPG  G0032277.JPG  G0032277.JPG
G0032278.JPG  G0032279.JPG  G0032280.JPG  G0032281.JPG
UAV survey, June 18, AM 5:30-6:00, 2016
in Bhainsepati

Take-off and land on NSET building
Under insufficient light condition (before 6AM), flying the lower altitude does not make the better quality due to shaking caused by the faster image flow.
Discussion

Biggest challenge was UAV permission

It took too long and too much efforts to obtain the UAV flight permission even for the purpose of damage assessment by a government agency.

➔ You need to wait for months after a disaster.
(or predict earthquakes few months in advance)

UAV is allowed to fly only before 6 AM in Kathmandu Valley
➔ Only single 30 minutes flight per day after sunrise, under insufficient light condition, only in May, June and July.

How to more quickly assess the damage if another disaster occurs tomorrow
1) Nepali government streamlines the process of application and permission, or provides a whole-year permission to a particular agency for a particular purpose.

2) CAAN defines “no-UAV height” near the airport only above which special permission is required.

Japanese regulation of height limit of UAV for your reference.
No “before 6AM” rule in Japan
How to quickly assess the damage by the next disaster

Helicopter is only the choice
GoPro on heli is a good option

Why GoPro? Heli can carry high res. full frame cameras. Because GoPro is easy to attach and operate, no need to ride heli, ultra-wide lens, waterproof, and available everywhere
Heli GoPro Test Survey
June 19, 2016

Picture avalanche debris in Langtang

Picture buildings in KV
Example result of Heli GoPro Survey

Boudha Road
Heli GoPro Damage Mapping (proposal)

Attach GoPro to every helicopter of disaster relief mission, or even search and rescue mission for quick damage assessment.

(coordination required, CAAN’s approval required)
Many people evacuated and stayed long in shelters, because they were hit by two big earthquakes in two days, similar to Nepali experience.

⇒ Even quicker ‘quick inspection’ is needed

It took many days or months to assess the damages of houses for government’s compensation for each household.

⇒ Quicker damage survey is needed

However, number of engineers is limited.
How to accelerate the process of earlier recovery

Triage of damage survey

Prioritizing the areas of dispatching engineers, by preliminary quick photo survey using Heli, UAV, Car, Motorbike with GoPro
Another challenge: How to quickly view the damages of hundreds of buildings

Ortho-mosaic photo is useful for mapping, but not useful for damage assessment because it shows only roofs.

3-D model is useful to measure the heights, but not useful for damage assessment because of low resolution and deformation.
Original oblique photos are best to see the damage

But, how to identify each buildings in hundreds of photos?
PhotoScan™ is a useful tool for the purpose,

But we need a simper tool without time-consuming data processing by PhotoScan
Conclusions

- UAV is supposed to be a useful tool to assess the damage and monitoring rehabilitation of Nepal from the Gorkha earthquake.
- The system of UAV regulation and permission of Nepal should be streamlined, especially for quick damage assessment.
- Helicopter is currently the best alternative. A method of data collection should be standardized.
- Efficient way of browsing oblique photos of individual buildings in hundreds of photos should be developed.

Future plan

1. UAV survey in Singati, Dolakha (permission is expected)
2. Process the data for mapping buildings and topos
3. Establishing “Heli-GoPro” method
UAV operation training
for future possibility of utilizing UAV in Nepal

Friday, June 24 at
Kathmandu University Campus
AM 11:00-12:00 Seminar
PM 1:30-4:00 Assembling, Configuration, Mission planning, and demo flight
Dherai dherai dhanyabaad

Domo arigato

KVDA  ChubuU.  NIED  NSET

6AM after the flight, Jun 7, 2016, in Khokana