

## APPLICATION OF DIGITAL PHOTOGRAMMETRIC SYSTEM FOR DIMENSIONAL MEASUREMENT AND 3D MODELLING



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## INTRODUCTION

- Digital close range photogrammetry (or vision metrology or videogrammetry) has been successfully applied (for measurement and 3D modeling) in many applications.
- Areas of applications [examples]: industrial measurement, archeology, architecture, ....
- Important current development in digital close range photogrammetric systems: full automation of the measuring process.
- Photogrammetric systems...range from low accuracy (or low end) to high accuracy (or high end).

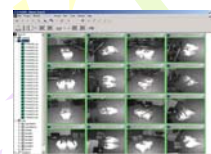
## INTRODUCTION

- This study:  
Applications of low accuracy (using normal digital camera and PHOTO MODELER 5.0 software) and high accuracy (using V-STARS system) digital close range photogrammetric systems for dimensional measurement and 3D computer modeling (using RHINOCEROS 3.0 software) of several objects.

## HIGH END SYSTEM

- V-STARS (Video Simultaneous Triangulation And Resection System) is a high-accuracy digital close range photogrammetric system, developed by GSI USA.
- V-STARS: automation of the entire measurement process [high-resolution intelligent camera (INCA), special targets (high contrast retro-reflective coded targets, autobar, scalebar), special processing software].
- Typical accuracy of V-STARS is better than 10 ppm or 1:100,000 (i.e. about 0.050mm (or 50 micron) on a 5.0m object).

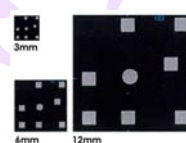
## System Components



software



camera



coded target



retro target



autobar

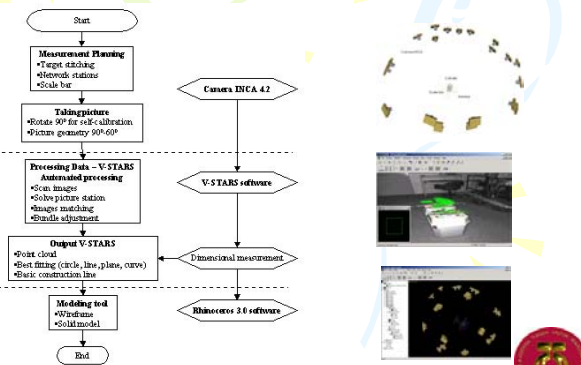
## V-STARS/S

- INCA camera:4.2 megapixels resolution, high accuracy (advanced calibrations techniques), robust, portable, easy handling, image compression up to 10% from original size and automation in measurement.
- Target [high contrast retro-reflective targets]:coded targets to control the measurement network [min 4 in an image], AutoBar for defining the origin of the measurement, scale bar (invar) with retro target to scale the measurement.
- Software: V-STARS software automatically processes the images [recognises coded targets] and the coordinates of points of interest computed using photogrammetric techniques and triangulations, high accuracy (1:120,000), fast.

## THIS RESEARCH

- Applications of V-STARS (using single camera-off line) for measurement of several models
- By adopting simple measurement steps, the accuracy of sub-mm level is easily achievable
- V-STARS provides the output in \*.igs (IGES) format, for 3D modeling using Rhinoceros.

## Measurement Procedure: V-STARS



## LOW END SYSTEM

- PHOTOMODELER is a windows-based program that helps user to extract measurement and 3D models from photograph or images.

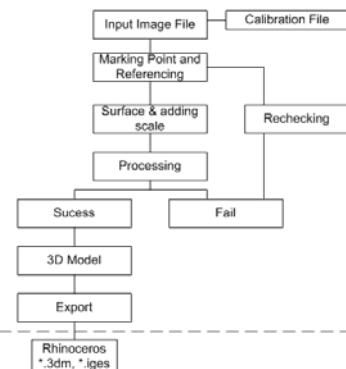


## Image Acquisition

- Canon IXUS S400 PowerShot
- Resolution of 4 Megapixel



## Processing: Photomodeler 5.0



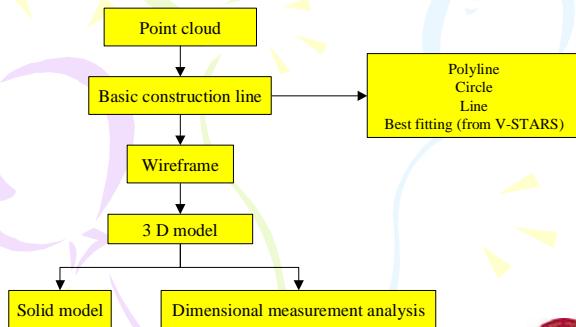
## Comparison: V-Stars vs Photomodeler

Comparison	V-STARS	Photo Modeler 5.0
Camera	INCA 4.2 megapixels	All digital camera
Software	VSTARS	Photo Modeler 5.0
Price	High (from US\$160k)	Low (from US\$3k)
Accuracy	Micron	sub-mm to cm
Target	Retro reflective	Retro Reflective, Artificial & Natural Target
Network	Coded	Retro Reflective, Artificial & Natural Target
Target recognition	Automatic	Semi-Automatic + Manually digitize
Dimensional measurement	Solid Module (geometry analysis)	3D Model
Modeling	Third party software (e.g. Rhinoceros 3.0)	3D View
Image capturing time	Less than 10 minutes	Less than 10 minutes
Data processing time	Less than 5 minutes	Depends on object or targets

## 3D MODELING: Rhinoceros 3.0

- RHINOCEROS: a commercial 3-D NURBS (non-uniform rational B-spline) modeling program for Windows. Among its capabilities are: generation of wireframe, generation of solid 3D model, and dimensional measurement.
- This research...developed procedure for 3D modelling using Rhinoceros 3.0: Import \*.igs or \*.3dm data from V-STARS and PHOTOMODELER; form basic construction line (using line and polyline functions); create wireframe; create solid 3D model from wireframe; and measure for dimensional measurement.

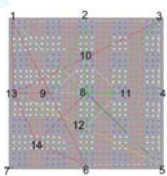
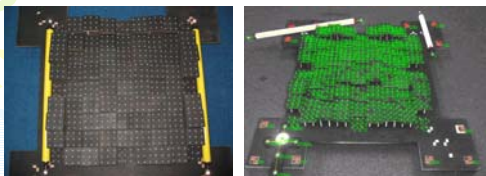
## 3D Modelling



## RESULTS

- V-Stars vs Photomodeler
- 3D modeling: V-Stars & Rhinoceros
- 3D modeling: Photomodeler
- V-Stars vs CMM vs XYZ [accuracy]

## 1. V-Stars vs Photomodeler



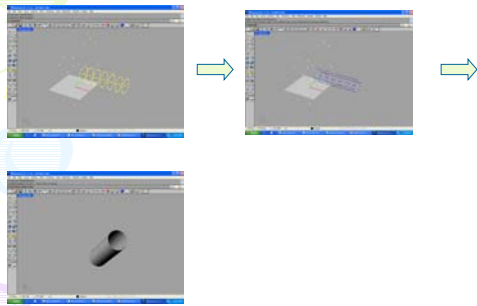
- The test object with retro targets
- 3 scalebars to check the distances
- Comparison: only 30 measurement [13 pts]

## Differences of measurement

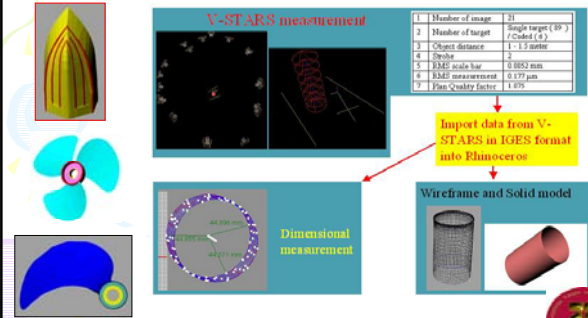
- The differences between V-STARS and PHOTOMODELER are between -0.6mm to 0.6mm (i.e. mm level).
- 3 Scalebar distances:
- Scale bar 1 (known=572.000mm): 572.000 mm (Vstars), 572.000 (Photomodeler)
- Scale Bar 2 (known=572.051mm): 572.051mm (Photomodeler)
- Scale Bar 3 (known=322.000mm): 322.000 (Vstars)
- V-STARS is very consistent, and PHOTOMODELER is capable of giving mm level accuracy

No	Measurement		Actual Distance (mm)		Differences
	From	To	VSTARS	Photomodeler	
1	1	2	260.236	259.999	0.237
2	2	3	262.701	262.356	0.345
3	3	4	261.790	261.332	0.458
4	4	5	257.603	257.309	0.294
5	5	6	260.312	259.864	0.448
6	6	9	121.312	121.213	0.099
7	9	10	168.335	168.256	0.079
8	10	11	167.504	167.389	0.214
9	11	12	167.708	167.447	0.261
10	1	5	736.701	736.538	0.163
11	2	6	523.007	522.764	0.243
12	8	5	369.511	368.931	0.580
13	8	11	371.107	370.592	0.515
14	12	3	459.041	458.469	0.572
15	2	9	285.516	286.134	-0.618
16	4	9	380.873	380.472	0.401
17	14	3	532.239	532.079	0.160
18	14	5	581.947	581.733	0.214
19	13	3	621.957	621.449	0.108
20	6	13	198.706	199.470	0.236
21	1	14	259.449	259.069	0.380
22	14	9	144.598	144.461	0.137
23	13	14	199.769	199.478	0.291
24	8	13	255.752	255.475	0.277
25	6	13	198.706	199.470	0.236
26	1	6	583.489	582.597	0.892
27	11	8	118.419	118.262	0.157
28	8	3	367.196	366.736	0.462
29	13	1	447.633	447.455	0.178
30	5	2	583.312	583.055	0.257

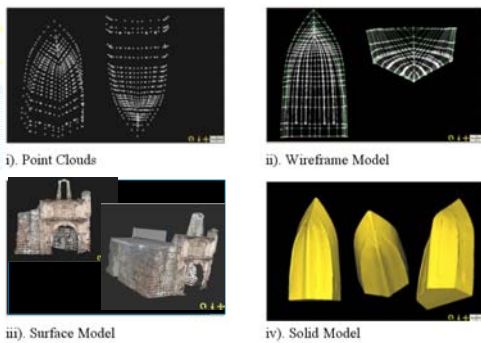
## 2. Results – Modelling (Rhinceros 3.0)



## Results – Modelling (Rhinceros 3.0)



## 3. Results - Modelling (Photomodeler)



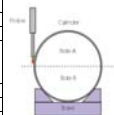
## 4. Accuracy analysis



### Accuracy: V-STARS, XYZ, CMM



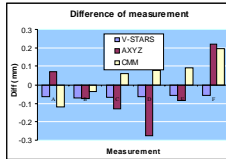
Section	Number of observed targets			
	V-STARS	XYZ	CMM (interval 5mm)	
			Part A	Part B
A	12	7	33	31
B	12	7	32	31
C	12	7	33	32
D	12	7	32	32
E	12	7	34	32
F	13	7	34	30
G	12	7	32	30



- A cylinder (i.e. PVC pipe) with known radius (45 mm)
- The cylinder was divided into 7 sections from A to G.
- All the systems use different number of targets.
- V-STARS & XYZ: camera & theodolites moved!
- CMM: points were automatically measured at 5mm interval [2 sides A & B because CMM platform is rigid!]

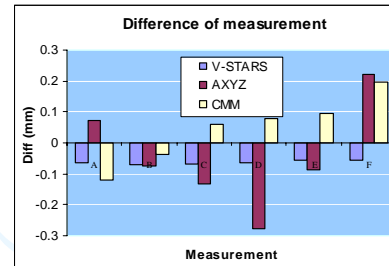
### Best fitting curve: V-STARS, XYZ, CMM

Section	Radius of the cylinder (known value 45 mm)			Difference (known 45mm)		
	V-STARS/S	XYZ	CMM (mean)	V-STARS/S (target thickness=0.5mm)	XYZ	CMM
A	44.592	44.449	45.184	-0.092	0.051	-0.184
B	44.563	44.428	45.121	-0.063	0.072	-0.121
C	44.571	44.575	45.038	-0.071	-0.075	-0.038
D	44.569	44.633	44.941	-0.069	-0.133	0.059
E	44.565	44.776	44.923	-0.065	-0.276	0.077
F	44.556	44.585	44.906	-0.056	-0.085	0.094
G	44.556	44.278	44.804	-0.056	0.222	0.196



- The differences between all systems are within sub-mm, indicating that all systems are highly precise.
- V-STARS: fastest (although off-line mode), the most consistent
- V-STARS & XYZ are more practical than CMM due to their mobility.

### Accuracy Analysis



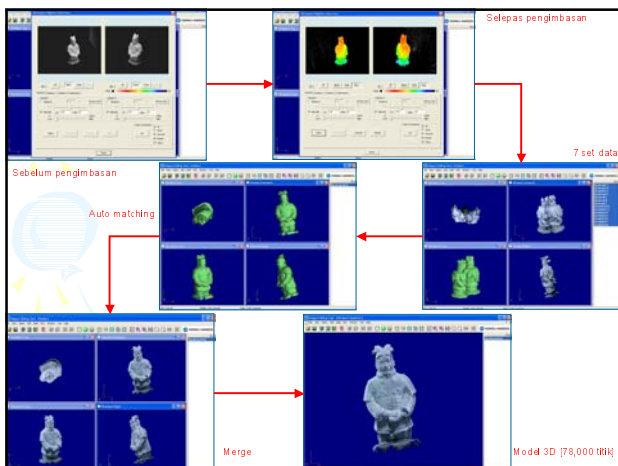
Differences: 0.1mm to 0.2mm

### CONCLUSIONS

- This research: Applications of low accuracy (using normal digital camera and PHOTOMODELER) and high accuracy (using V-STARS system) digital close range photogrammetric systems for dimensional measurement and 3D modeling of objects.
- The results obtained show the practicality of both systems, with accuracy ranging from several micron (for high accuracy system) to several mm (for low accuracy system).

### NEXT?

- Laser scanning [Vivid910]-rapid 3D model.
- Rapidform-3D modeling software.
- Object: Terra-cotta model!



### THANK YOU!

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